FORECASTING AND EXPLANATORY MODELS
FOR MIDDLE EASTERN DEFENSE BUDGETS:
A CASE STUDY OF SAUDI ARABIA

THESIS

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AFIT/GOA/ENS/96M-06





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# FORECASTING AND EXPLANATORY MODELS FOR MIDDLE EASTERN DEFENSE BUDGETS: A CASE STUDY OF SAUDI ARABIA

THESIS

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Robert S. Renfro, II

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## Abstract

This thesis focuses on means of forecasting Saudi Arabian military expenditures and the effect of such expenditures on the United States. Saudi Arabia is one of the largest purchasers of American arms and will continue to be for many years. Saudi Arabia has experienced several recent changes in economic and government policy.

Using exponential smoothing techniques and linear regression, we isolated several trends in Saudi Arabian military expenditures. Using two linear regression models, military expenditures were then forecast with excellent results. The first model considered the assumption that Gulf War spending would continue. This model uses Saudi Arabian Gross Domestic Product lagged by three years and the current year force size as explanatory variables. The second model considers the assumption of post-war reductions and is based only on the Saudi Arabian Gross Domestic Product lagged by three years.

Using decision analysis, it was possible to consider the implications of these forecasts for the United States. The decision analysis model considered several relevant contemporary issues, including succession of the Saudi Arabian King, the Foreign Military Sales policy of the United States, associated uncertainties, and risk.

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## I. Introduction

The primary focus of this study is to examine Middle Eastern military expenditures from a forecasting perspective using Saudi Arabia as a case study. The desired product is a model which accurately forecasts Saudi Arabian military expenditures. This study was proposed and is sponsored by the Office of the Under Secretary of the Air Force for International Affairs (SAF/IA) and, specifically, the Saudi Arabia Division (SAF/IAS). The Middle East is not only a region of much national interest to the United States due to oil reserves and strategic location, but it also represents a large market for U.S. goods and services (51:1).

Before gathering data and conducting analysis, it is necessary to establish the historic relevance and present day context of this study. The significant area of concern in this study is the U.S. defense industry. Due to reductions in U.S. defense spending, defense contractors have a growing dependence on foreign markets (3:48). The Middle East represents most of these foreign sales (3:48).

A large portion of past sales have been to Saudi Arabia, as will be the bulk of future sales (3:48).

The Middle East, and the world in general, can be thought of as having three types of customers: paying customers, non-paying customers, and non-customers (51:2-3). Paying customers are those who buy goods and pay in hard currency. Examples of paying customers in the Middle East are Saudi Arabia and Kuwait (50:118; 51:2-3). Non-paying customers are those customers who use aid, purchase credits, or similar methods, to acquire goods from the country providing the aid (i.e. little net monetary gain to the exporting country). With respect to United States arms sales, examples of non-paying customers in the Middle East include Egypt and Israel (35:1; 51:3). Non-customers are countries who either choose not to purchase from a given supplier or who are restricted from purchasing from a supplier either by the supplier or by an international body such as the United Nations. With respect to the United States and many other countries, Iraq and Libya are examples of non-customers in the Middle East (51:3; 39:46). When considering real monetary gains for an exporting country, paying customers are of the most concern.

Saudi Arabia is, and has been for many years, a major paying customer for the goods and services it imports from the United States and other countries (50:117-118). However, the concern is that, due to many events which have

occurred in recent years as well as projections for the next decade, this behavior could change or be significantly reduced. The Gulf War resulted in significant policy changes in Saudi Arabia (50:118). The immediate effect was that Saudi Arabia became the major world purchaser of U.S. arms in 1990 (50:118). However, the after effects and cost of the war resulted in a hard currency shortage in Saudi Arabia resulting in a need to reduce government spending (8:1).

Threats to the security of Saudi Arabia still remain. There are the relentless hints and military gestures of Iraq following the Gulf War (18:9). Iran continues to be a threat to Saudi Arabia because of its growing military strength which includes submarines and weapons of mass destruction (37:53). Also, Saudi Arabia is concerned about its historic border tensions with Yemen (13:14; 54:17). The problems with Yemen were amplified during the Gulf War when Yemeni workers were expelled from Saudi Arabia and restrictions were placed on Yemeni-owned businesses (50:118).

It can be seen that in nearly every direction lies a threat to the security of Saudi Arabia. Reflecting an understanding of these threats, military expenditures are among the largest expenditures in the Saudi Arabian national budget (6:12; 52:3).

Saudi Arabia is beginning a period of significant change. The Saudi Arabian, dollar-based, economy has been affected by the recent fluctuations of the dollar on international currency markets (14:13). The Saudi Arabian government was recently reorganized and the succession of the King will be an issue for upcoming years (47:37; 48:14). Even in this time of change and declining budgets, the 1995 Saudi Arabian defense budget still remained the largest single expenditure for the Kingdom and represents a higher percentage of total expenditures than in 1993 (6:12).

Some might believe that these changes are of little interest to most Americans; however, nothing could be further from the truth. These changes not only impact international diplomacy, oil trade, and the value of the U.S. dollar; they also directly impact the American industrial base (18:9). As U.S. defense spending declines, defense contractors can compensate for reduced domestic sales through export sales (4:37; 36:41). Although declining due to the reasons already mentioned, Middle Eastern markets will remain the most lucrative for U.S. defense contractors due to a high demand in the region (37:52). Further, potential customers prefer American goods, proven in the Gulf War, over the goods of other possible suppliers (37:52). These sales not only fill the pockets of defense contractors, but each sale and related service agreement on a project represents significant

numbers of jobs for Americans (4:37). Current needs in Saudi Arabia include modernizing and expanding its tank force, additional Airborne Warning and Control System (AWACS) aircraft, establishing an antisubmarine warfare capability, and related service, training and support (37:52). Through countertrade agreements, these sales also build strong relationships between the U.S. defense industry and Saudi Arabian companies. An example of this is the recent agreement for co-production of M1A2 electronics between Saudi Arabia's Advanced Electronic Company and General Dynamics (43:15).

The value of forecasting Saudi Arabia's military expenditures for years to come is apparent. At a national level, this information is valuable for economic planning, predicting changes in the American industrial infrastructure, and evaluating strategic concerns in the Middle East. At a corporate level, defense contractors are very concerned with issues surrounding production, planning, and manpower requirements. The individual American citizen is also affected in many ways, from variations in petroleum prices to changes in inflation and the value of the dollar. Some citizens' future careers may even be lost, changed, or created due to many of the factors already discussed (4:37).

This study begins by building an understanding of the dynamics of the Saudi Arabian economy to determine cause and effect relationships. Based on this information, specific

data is gathered on the factors which influence these relationships. These data were taken from readily available, internationally recognized sources. Ideal factors are those which can be traced back to the 1970s, are annually recorded, do not possess or have a means to remove inflation elements, and can be represented numerically. Further, since the desire is to forecast military expenditures, factors whose relationship to military expenditures are lagged by one or more years are most relevant. Factors are likely to a have a lagged relationship any time a planning period exists (41:204). This is especially common in macroeconomic applications (41:204). This means that although a government may make significant changes in economic policy today, the effect may not manifest itself for some time, even years, into the future.

These factors come from and are influenced on many levels, including international, regional, the Gulf Cooperation Council, Saudi Arabia's national interests, Saudi Arabia's national budget, and Saudi Arabia's military structure and budget. Note that purchases from the United States are a subset of Saudi Arabia's aggregate military expenditures; however, as stated, the United States is the preferred supplier.

The approach taken in this study was to first gain an understanding of the processes underlying Saudi Arabian

economic decision making. The objective being to capture military expenditures as an aggregate. The relationship between Saudi Arabian military expenditures and U.S. Foreign Military Sales (FMS) was then considered. This study not only leads to building an explanatory model of Saudi Arabian military expenditures, but uses this information to make inferences regarding U.S. FMS and the resulting effects on the U.S. industrial base.

Implications of this study extend beyond the immediate issue of forecasting Saudi Arabian military expenditures to establishing a paradigm for examining the behavior of other countries, inside or outside of the Middle East, with similar regional concerns, an oil-based economy and/or an economy strongly influenced by the U.S. dollar.

# II. Literature Review

Prior to building a model for Saudi Arabian military expenditures, it is necessary to gain an understanding of relevant economic issues. There are three main topics on which this review focuses. First, factors which may affect Saudi Arabian military expenditures are researched. Second, methods for modeling national economies and military expenditures are considered in order to determine which would be most applicable to Saudi Arabia. Finally, previous attempts at modeling Saudi Arabian economics, military expenditures, or military purchases are examined.

## Saudi Arabian Government and Economy

When considering Saudi Arabia, it is necessary to mention its system of government which is described as "an Arab and Islamic sovereign state" (46:3). The constitution of Saudi Arabia is the Holy Quran and the legal system also follows Shariah, Islamic law (46:3). Saudi Arabia is governed by a Council of Ministers and the King, who also acts as prime minister (46:3). The King has direct access to public opinion through the Consultative Council, called the Majlis Ashoura, which also serves as a legislature (46:4).

Saudi Arabia's economy centers around international trade, specifically petroleum related exports (50:117). As

such, Saudi Arabia's economy is influenced on many levels. For the purpose of this study external influences on three levels are considered: international, regional, and within the Gulf Cooperation Council (GCC). There are also factors within Saudi Arabia which will affect government appropriations. These factors are considered at five levels: national issues, national budget, defense budget, defense purchases, and defense purchases from the United States.

Since the Saudi Arabian economy relies heavily on the oil trade and is tied directly to the U.S. dollar, the effects of changes in the international oil market are very relevant considerations in relation to Saudi Arabia (50:117). Factors on this level include the value of the U.S. dollar on international currency markets, global oil prices and demand, and Organization of Petroleum Exporting Countries (OPEC) quotas. Saudi Arabia as a member of the United Nations, World Bank, and International Monetary Fund, is also influenced by the decisions, resolutions, and related treaties of these organizations (45:5).

On a regional level, Saudi Arabia is subject to influences from several different directions. Saudi Arabia is a member of the Arab World, represented by its membership in the League of Arab States (LAS) (45:5). Saudi Arabia is a member of the Islamic World, represented by its membership in the Organization of the Islamic Conference (OIC) (45:5).

Saudi Arabia is located in the Middle East which is described as Libya, Egypt, Israel, Iran and those Arab countries not lying in North Africa. This last regional distinction is the least binding in terms of legislated decisions; however, the Middle East contains Saudi Arabia's greatest military threats, Iraq and Iran, which gives rise to the ongoing arms race in the region (7:8).

Within the Arab World, there exists certain "inter-Arab" groupings as well (50:29). Saudi Arabia is a member of one such organization, known as the Gulf Cooperation Council (53:17). Other members of this organization all lie on the Arabian Peninsula and include Bahrain, Kuwait, Oman, Qatar, and the United Arab Emirates (53:17). Members of this organization have many common economic goals and concerns (53:17). Not surprisingly, the members also have similar military concerns and threats. Member states, such as Saudi Arabia, have several economic and military obligations to other members.

On a national level, there are several issues of concern which affect Saudi Arabian decision making and military expenditures. These include leadership and the succession of King Fahd and the King's view of the military, policies on privatizing industry, the use of foreign labor, and the strength of religious influences. Saudi Arabia has experienced four successions of the king since 1953 with King Fahd in power today (28:82). Crown Prince Abdullah,

who also heads the Saudi Arabian National Guard, will succeed King Fahd (28:82; 48:14). He will in turn be succeeded by Prince Sultan, who currently serves as the Minister of Defense (28:82; 48:14). Clearly, these leaders all have a strong interest in the military. Present policy has encouraged privatization, decreases in foreign labor at the executive level, and a continued emphasis on religion (52:3).

The Saudi Arabian national budget and planning process dictates certain constraints for military expenditures. According to Saudi Arabian officials, "Saudi Arabia's economic system is based on free and private enterprise" (44:1). Saudi Arabia's budget is presently, and has been since 1990, experiencing a deficit (52:3). Although some foresaw recovery as early as 1992 (17:VII), this debt was severe enough to cause Saudi Arabia to restructure its debt payments to the U.S. government and U.S. defense contractors in early 1994 (49:46; 38:22).

In response to this budget deficit, the Saudi Arabians have reduced spending, are expanding the private sector and are diversifying their economy to increase revenue (52:3). "A report issued by the Ministry of Finance and National Economy . . . estimated that the Saudi gross national product (GNP) will grow by 16 percent this year [1995]" (52:3).

Economic growth is planned to continue throughout the duration of Saudi Arabia's Sixth Development Plan which spans the years from 1995 to 1999 (44:8). Although moving in the direction of these goals of increasing private industry revenues and growth in GNP, the current budget deficit would suggest that Saudi Arabian economic recovery may be slower than estimated. The present conditions in Saudi Arabia have been described as having private investors responding to short term economic changes created by government expenditures (30:1367-1375).

It is important to note that the Saudi Arabian Embassy's report on these budget plans did not mention any changes in the defense budget (52:3). The defense budget planning process in Saudi Arabia has not been as public as the other changes and conditions which have already been mentioned. However, it is not difficult to suspect that the defense budget will be dictated in part by the following factors: national revenue, perceived threat, current structure and requirements, and leadership (12:255-257). This is the level where this study will focus its efforts initially to establish a relevant methodology.

Defense purchases are a subset of defense spending and hinge on many of the same elements. However, examining defense purchases or arms imports in a quantitative sense is a bit more complicated due to the elements involved in reporting (26). To a large degree this is due to the

deceptive nature and lack of reporting involved with countertrade agreements (26). Countertrade is basically a system of barter between nations whereby one asset of value is traded for another (23:127). This is very common among oil producing countries, which barter oil for other goods (23:127).

> Saudi Arabia has turned to countertrade, particularly on big ticket military purchases, as oil revenues have fallen from their previous highs. ... As long as the oil market remains soft and budget deficits grow, countertrade may be expected to increase (23:127).

These transactions involving billions of U.S. dollars worth of goods do not always appear on balance sheets as direct expenditures (23:127).

Saudi Arabian defense purchases from the U.S. are a subset of Saudi Arabia's total defense purchases. Military spending decisions which have been examined to this point are based solely on those factors facing Saudi Arabian decision makers. When considering purchases from the U.S., however, Saudi Arabian policy and U.S. policy both play a part. Issues such as the U.S. Congress (31), U.S. competitiveness (20), and availability of equipment are of particular interest (26). The United States has and continues to be very competitive in Middle East trade in general and in the arms trade specifically (19:4-5). If the U.S. wishes to maintain this competitive position, an emphasis must be placed on technological advancement, after sales service, and pricing (19:5). Saudi Arabia, the

world's largest arms importer, continues to import the majority of its arms from the U.S. (42:77). Also, the U.S. government is anticipated to be more supportive of trade with the Middle East in the form of export credits and trade promotion in the future (19:5).

Modeling National Economies and Military Expenditures

Having examined the factors and levels of influence which may play a role in Saudi Arabian military expenditures, possible methods for modeling and forecasting national economies and military expenditures must be examined. There are several forecasting techniques which may be applicable. These techniques include trend analysis, classical forecasting, econometrics, simulation, and decision analysis (10:1,313-317; 41:412-416).

All of these techniques have different characteristics. Characteristics which are important in this study include fidelity, explanatory power, time span for making reasonable forecasts, number of factors required, the size of the database, and the ease of updating the database. Fidelity means the degree to which a specific technique will produce results close to actual spending levels. This characteristic is the most important; however, the technique which yields the greatest fidelity can only be discovered through the development, testing, and analysis of models which incorporate these techniques.

The other characteristics should be considered before beginning analysis. Explanatory power is the degree to which a technique portrays the decision making process. The best case would be a technique which correctly portrays and incorporates all aspects of a decision making process. The worst case is one which is purely a numerical extrapolation of past information. The time span for making reasonable forecasts is the number of periods into the future that a technique makes useful forecasts. The number of factors and size of the database may often be related to each other. In this case study, a smaller database is preferable as it is easiest to maintain in the future. The ease of updating refers to the degree of difficulty in adding new information to an existing database.

In general, trend analysis and classical forecasting extrapolation techniques have very large time spans for making forecasts. They use only the main factor (i.e. the one to be forecasted). These techniques have a database containing past values for this factor, and are easy to update; however, they lack explanatory power (41:415).

Econometric models, also known as regression or least squares models, may include only data for the main factor. In this case, the technique is similar to the classical forecasting techniques except it has a much shorter time span for making forecasts (41:415). Econometric models which use factors other than the main factor to make

forecasts of the main factor require a database which contains past values of all factors. Econometric models are still fairly easy to update, have a shorter time span for making forecasts, and may have significant explanatory power (41:416).

Econometric models can be expressed in equation form, relating variables quantitatively (41:xv). In econometric models, data are used to estimate parameters of the equation and theoretical relationships are tested statistically (41:xv). When data are ordered in time, the data are termed time-series. Econometric, time-series forecasting models examine past behavior and attempt to use the information gained to forecast future behavior (41:xvii). This can be as simple as a linear extrapolation of past behavior or may make use of any number of independent explanatory variables (41:xvii). Time-series models have been found useful when little is known about the underlying process that one is trying to forecast (41:xvii). Time-series models have proven useful in forecasting many economic processes (41:xvii).

Simulations have many of the characteristic of econometric models; however, they often use probability distributions based on past behavior rather than maintaining large databases of past observations (27:1). Simulation models attempt to imitate, or simulate, a process based on a set of assumptions about the behavior of the process (27:1).

Simulations have been used in the past for analyzing financial and economic processes, among many other uses (27:2). Simulation studies often require a large amount of time to complete due to their stochastic nature which requires multiple runs of a model to estimate a process under a given set of assumptions (27:3).

Decision analysis has many of the characteristics of simulations. It is usually implemented deterministically, reducing total analysis time, and can be easily modified to consider future events (10:313-315). Unlike the other techniques, decision analysis is centered around some fundamental question or set of questions (10:2-3).

Decision analysis models often use influence diagrams to provide a graphic representation of a decision problem (10:34). Influence diagrams consist of nodes and arcs (10:34). Nodes represent decisions, known values, and uncertainties (10:34). Directed arcs between nodes are used to show how nodes influence each other (10:34). Uncertainty nodes can use known probabilities, discrete probability distributions, and continuous probability distributions to determine the outcome of the uncertain events modeled (10:19-20,213-233). The easiest way to use continuous probability distributions is to approximate them with a discrete distribution (10:219).

A technique which has been found useful and accurate for many applications is the Extended Pearson-Tukey method

(10:244). This method is most applicable for symmetric distributions such as the normal distribution (10:220). This method is useful when little information is known about an uncertain process because this method only requires the user to know a high and low response (which should approximate the 0.05 and 0.95 fractiles) and a median response (10:220). The high and low response receive a probability of 18.5% and the median response receives a probability of 63%. Techniques such as the Extended Pearson-Tukey method, make decision analysis a very useful tool when little information is known about the uncertainties involved in making a complex decision.

Previous Efforts at Modeling Saudi Arabian Economics

Previous attempts at modeling military expenditures and arms trade have used some of the techniques which have already been discussed and others which have not (25:295-333); however, most of the resulting models use factors from three basic domains. The first are models which use Gross Domestic Product (GDP), Gross National Product (GNP), and balance of payments (25:297-322). The second group are models which use non-economic variables such as threat, desired military capacity, and internal violence (25:322-324). The third group are models which use repair, replacement, and demand information for known and proposed weapons systems (1:221-254; 2:1-22). Other past endeavors

have combined elements from two or more of these domains (11:85-109) and still others have preferred a more subjective approach using political and military patterns (15;16).

The issue of using GDP, GNP, and balance of payments has caused a great deal of discussion. GDP is "the market value of all final goods and services produced in a year within a country's borders" (5:139). GDP can also be viewed in terms of expenditures since a market must have both buyers and sellers; in this sense, military expenditures is some portion of GDP (5:142). It is important to note "final goods and services" only includes goods available to the final consumer (5:139). GNP is "GDP plus receipts of factor income from the rest of the world minus payments of factor income to the rest of the world" (5:145).

> GDP excludes income from factors of production that are located in foreign countries but owned by domestic residents and includes income from factors of production that are located in the domestic country but owned by foreign residents, and GNP is just the opposite (5:149).

Some analysts have argued that GNP and military expenditures vary directly (25:319). Others believe that military expenditures of a nation are related to the size of its economy in terms of its resource base or productive capacity measured by its GDP (25:320). Others argue whether or not defense spending itself promotes growth in an economy (34:283-305). It is also recognized that to use any of

these measures, it is necessary to use appropriate exchange rates and deflation factors to measure output in terms of constant values (10:149-153; 25:317).

Most previous attempts at modeling or describing Saudi Arabian military expenditures or arms purchases have been very general in nature, looking at trends (15;16) or using the repair, replace, demand approach (1;2). These methods have their merits and contribute to a general understanding of Saudi Arabian economic policy making; however, they lack the numerical precision of an analytical forecasting approach. With few exceptions, these previous stùdies have not produced very accurate forecasts due to their narrow focus. They approach the problem by looking at individual U.S. Foreign Military Sales (FMS) programs to Saudi Arabia. As noted previously, such a FMS program has many elements which are not dictated solely by Saudi Arabian decision makers and in most cases involve factors which are not reported in dollar figures on balance sheets.

In Chapter III, Saudi Arabian military expenditures are forecasted using several analytical forecasting techniques which have been found useful in modeling economic processes. These techniques include linear regression and various classical forecasting techniques. For each technique, models are built and compared.

## III. Methodology

Prior to forecasting future Saudi Arabian military expenditures, it is necessary to build an understanding of past military expenditures. Based on the desired characteristics of a forecasting model discussed in Chapter II and the time series nature of military expenditures (21:21; 32:355), three types of forecasting models for military expenditures were considered. These included a naive forecasting model (32:73), smoothing techniques (32:64-119), and linear regression (21:21-24). As discussed in Chapter II, these models are ones that have been used with varying degrees of success in previous efforts to model national economies. Autoregressive, moving average (ARMA) models were not considered due to the small sample size of annual Saudi Arabian military expenditures. Further, ARMA models are useful for forecasting autocorrelated data. As will be discused in Chapter IV, Saudi Arabian military expenditures do not appear to be autocorrelated.

Also, recall from Chapter I that lagged relationships due to a planning process are also very common in macroeconomic data. The goal of the Saudi Arabian economic planning process mentioned in Chapter II, as defined by the Saudi Arabian Ministry of Finance and National Economy, is to increase revenue. This would be represented by an increasing trend in the Saudi Arabian GDP, GNP, and,

possibly, military expenditures. If this planning process or any other major events which affect the economy occur at regular intervals, it is also likely that cycles exist. The types of models used in this chapter can account for lags, cycles, or trends in the data.

Modeling Saudi Arabian Military Expenditures

The modeling effort used data for Saudi Arabian annual military expenditures from 1974 to 1992, as reported by the U.S. Arms Control and Disarmament Agency (ACDA). These data were converted to common 1990 values using Saudi Arabian GDP deflation factors published by the International Monetary Fund (IMF) (55; 56). The year 1974 was selected as the starting date because Saudi Arabia started to experience significant benefits to its economy from its oil export revenue at this time (24:628). It is important to note that complete data after 1992 are not available from internationally recognized sources at this time and any reported figures are themselves estimates (24; 56).

Based on the previous modeling efforts and relevant factors influencing the Saudi Arabian economy discussed in Chapter II, independent variables considered in this study as possibly influencing military expenditures were gross domestic product (GDP), gross national product (GNP), aggregate military force size, and annual oil export revenue. GNP and force size information were also taken

from ACDA reports (55; 56). GDP and annual oil export revenue data were taken from IMF reports (24). Note that all the data presented in the tables of this and other chapters has been rounded for ease of display and reading. Complete data sets for all factors considered and other calculations with the appropriate significant digits are located in Appendix A.

To evaluate models, it is necessary to establish a baseline. The baseline used in this study is a naive forecast. A naive forecasting model is a moving average over one period. In other words, the forecast is merely the value observed in the previous period. This model is considered the baseline for comparisons to other techniques. Thus, any method considered must provide more information than simply looking at military expenditures in year t and assuming military expenditures will be the same in year t+1. This model can be expressed as follows:

$$E(ME_t) = ME_{t-1}$$

where $ME_t$ is military expenditures in year t. For Saudi Arabian military expenditures from 1974 to 1992 in billions of 1990 dollars, this model produced the results presented in Table 1. Statistical measures of the error between the actual and forecasted values are also presented.

SSE is the Sum of Squared Error, $\Sigma(ME - E(ME))^2$, over the period of interest (1974-1992) (33:498,515). MSE is the Mean Squared Error, SSE/(n-df), where n is the number of

observations, in this case 19, and df is the degrees of freedom (33:516). For moving average and smoothing techniques df is zero. For linear regression models, df is equal to the number of parameters estimated in the regression function (33:516). RMSE is the Root Mean Squared Error, $\sqrt{(MSE)}$ (33:516). RMSE can be used as an approximation for the standard error (33:516). There is about a 67% chance that the actual $ME_t$ will lie within one standard error of $E(ME_t)$ and a 95% chance that the actual $ME_t$ will lie within two standard errors of $E(ME_t)$ (22:4-7).

**Table 1**

Naive Forecasting Model
(billions of 1990 dollars)

| **Year** | **1974** | **1975** | **1976** | **1977** | **1978** | **1979** | **1980** | **1981** | **1982** | **1983** |
|---|---|---|---|---|---|---|---|---|---|---|
| **ME** | 5.8 | 11.2 | 15.5 | 13.2 | 14.5 | 14.2 | 12.4 | 13.5 | 19.8 | 22.0 |
| **E(ME)** | 5.8 | 5.8 | 11.2 | 15.5 | 13.2 | 14.5 | 14.2 | 12.4 | 13.5 | 19.8 |

| **Year** | **1984** | **1985** | **1986** | **1987** | **1988** | **1989** | **1990** | **1991** | **1992** |
|---|---|---|---|---|---|---|---|---|---|
| **ME** | 18.9 | 21.2 | 21.0 | 19.1 | 16.6 | 16.5 | 22.9 | 34.9 | 33.0 |
| **E(ME)** | 22.0 | 18.9 | 21.2 | 21.0 | 19.1 | 16.6 | 16.5 | 22.9 | 34.9 |

SSE = 317.10 MSE = 16.69 RMSE = 4.09

For comparison, models with a smaller RMSE are considered better (32:114-117). Thus, any model tested must have a RMSE less than the naive forecasting model to recieve further consideration. Since MSE cannot be negative, a smaller RMSE implies that the MSE is also smaller. Using RMSE accounts for variations in sample size and degrees of freedom.

First, models applying smoothing techniques were examined. These models rely only on the factor being considered which, in this case, is military expenditures. A limitation of these types of models is that they neglect other sources of explanatory information. Models based on several different smoothing techniques which consider the possibility of level components, trend components, and cycle components in additive, multiplicative, and exponential forms were considered.

The model with the smallest RMSE of this type was Holt-Winters Exponential Smoothing with multiplicative seasonals (22:18-14) and a season (or cycle) of eight years. Multiplicative cycles imply that the cyclic effect in the model increases or decreases with time (22:18-14). Since data used in this study is annualized, seasonality will henceforth be referred to as cycling. Among those smoothing models tested, a cyclic model demonstrating the smallest RMSE is not surprising. As mentioned in Chapter II, Saudi Arabia uses development plans for major aspects of its economy. This eight year cycle observed in military expenditures may be a product of a similar planning process or event which occurs every eight years. The Holt-Winters exponential smoothing model can be described as follows (32:104-106):

Overall smoothing:

$$S_t = \alpha(ME_t/I_{t-1}) + (1-\alpha)(S_{t-1} + b_{t-1})$$

Trend smoothing:

$$b_t = \Gamma(S_t - S_{t-1}) + (1 - \Gamma)b_{t-1}$$

Seasonal smoothing:

$$I_t = ß(ME_t/S_t) + (1 - ß)I_{t-L}$$

Forecast:

$$E(ME_{t+m}) = (S_t + (b_t)m)I_{t-L+m}$$

where L is the length of the cycle, S is the constant or level component, b is the trend component, I is the cycle adjustment factor, and $E(ME_{t+m})$ is the forecast made at time t for m years ahead. Note that m=1 until the end of the observed period has been reached. Thus, it is not necessary to forecast more than one year into the future until making forecasts beyond 1993, in this case.

The parameters $\alpha$, ß, and $\Gamma$ all range from 0 to 1 and are used to vary the weight on the associated component. The values for these parameters were selected by considering every possible combination of values, restricted to two decimal places, and choosing the combination which resulted in the model with the least error. Using the following parameters, this Holt-Winters model produced the results presented for the mean (or constant), trend, and cycle components of military expenditures. End of period values are listed for 1992 and cycle adjustment factors for the last eight periods, 1985 to 1992.

| Parameters: | | End of period levels: | | |
|---|---|---|---|---|
| $\alpha$ = | 0.03 | Mean ($S_{1992}$) | | 26.09243 |
| ß = | 0.66 | Trend ($b_{1992}$) | | 1.014850 |
| $\Gamma$ = | 0.00 | Cycle ($I_t$) | 1985 | 1.095541 |
| | | | 1986 | 1.080451 |
| L = | 8 years | | 1987 | 0.966577 |
| | | | 1988 | 0.799807 |
| | | | 1989 | 0.795796 |
| | | | 1990 | 0.899379 |
| | | | 1991 | 1.166065 |
| | | | 1992 | 1.196384 |

These end of period values are all that is required to make forecasts beyond 1992. This is done by increasing m by one for every year forecast beyond 1992 and using the forecasting equation already described. It is also possible to use these end of period values to develop forecasts backward in time. Table 2 shows forecasts using this method for 1974 to 1992. For a more rigorous demonstration of this technique refer to Appendix B.

**Table 2**

Holt-Winters Exponential Smoothing
(billions of 1990 dollars)

| **Year** | **1974** | **1975** | **1976** | **1977** | **1978** | **1979** | **1980** | **1981** | **1982** | **1983** |
|---|---|---|---|---|---|---|---|---|---|---|
| **ME** | 5.8 | 11.2 | 15.5 | 13.2 | 14.5 | 14.2 | 12.4 | 13.5 | 19.8 | 22.0 |
| **E(ME)** | 8.6 | 11.9 | 13.2 | 13.0 | 13.7 | 13.1 | 11.6 | 12.2 | 14.7 | 20.4 |

| **Year** | **1984** | **1985** | **1986** | **1987** | **1988** | **1989** | **1990** | **1991** | **1992** |
|---|---|---|---|---|---|---|---|---|---|
| **ME** | 18.9 | 21.2 | 21.0 | 19.1 | 16.6 | 16.5 | 22.9 | 34.9 | 33.0 |
| **E(ME)** | 22.3 | 21.4 | 22.2 | 20.7 | 17.9 | 18.5 | 21.6 | 29.0 | 31.2 |

SSE = 106.34 MSE = 5.60 RMSE = 2.37

The next type of models considered were linear regression (or least squares regression) models. Note that these models by definition are aimed at reducing the sum of squared error (22:4-2) and can be easily compared to the

other models under consideration using RMSE which, as mentioned earlier, takes degrees of freedom into account. Linear regression models can use lagged observations of the factor under consideration, or they can be based on values of one or more explanatory variables which may also be lagged. A model using lagged values is one in which forecasts for a specific year are based on observations in one or more previous years, where the number of previous years defines the period of the lag (22:2-8).

As a baseline linear regression model, the most simple model was first considered. This model is one based on the trend of the factor under consideration, military expenditures, over the observed time period, years 1974 to 1992. Any linear regression model must have a RMSE less than the simple linear regression model to be further considered. Such a model must also have a smaller RMSE than the naive forecasting model to be competitive with the other models already tested. Linear regression models have several necessary assumptions, especially with respect to trends in error (21:282). These assumptions are addressed in Chapter IV for selected models. RMSE continues to be used for comparison; however, other relevant statistics are also reported and discussed.

As already mentioned, linear regression models use parameter estimates based on minimizing the squared error between observed and forecasted values. The simple linear

regression used to model Saudi Arabian military expenditures in billions of 1990 dollars can be described as follows for year t:

$$E(ME_t) = \alpha_0 + \alpha_1 t, \text{ where}$$

| Variable | Value | T-Statistic | 2-Tail Significance |
|---|---|---|---|
| $\alpha_0$ | -1986.7365 | -5.72 | 0.0000 |
| $\alpha_1$ | 1.0110706 | 5.77 | 0.0000 |

Probability(F-Statistic) = 0.000023

The parameter $\alpha_0$ is the axis intercept (i.e. the value of E(ME) when t equals zero). The parameter $\alpha_1$ describes the slope of the linear regression equation. A positive value for $\alpha_1$ indicates an increasing trend, a negative value indicates a decreasing trend, zero would indicate no trend. Forecasts based on this model are presented in Table 3.

**Table 3**

Simple Linear Regression
(billions of 1990 dollars)

| **Year** | **1974** | **1975** | **1976** | **1977** | **1978** | **1979** | **1980** | **1981** | **1982** | **1983** |
|---|---|---|---|---|---|---|---|---|---|---|
| **ME** | 5.8 | 11.2 | 15.5 | 13.2 | 14.5 | 14.2 | 12.4 | 13.5 | 19.8 | 22.0 |
| **E(ME)** | 9.1 | 10.1 | 11.1 | 12.2 | 13.2 | 14.2 | 15.2 | 16.2 | 17.2 | 18.2 |

| **Year** | **1984** | **1985** | **1986** | **1987** | **1988** | **1989** | **1990** | **1991** | **1992** |
|---|---|---|---|---|---|---|---|---|---|
| **ME** | 18.9 | 21.2 | 21.0 | 19.1 | 16.6 | 16.5 | 22.9 | 34.9 | 33.0 |
| **E(ME)** | 19.2 | 20.2 | 21.4 | 22.3 | 23.3 | 24.3 | 25.3 | 26.3 | 27.3 |

$R^2$ = 66.21%        Adjusted $R^2$ = 64.22%
SSE = 297.42        MSE = 17.47        RMSE = 4.18

The T-Statistic determines the probability that the related independent variable, t, helps to explain the dependent variable, ME (22:9-5). Hence, a 2-Tail Significance of zero is the strongest evidence a given

variable has explanatory power (22:9-5). 100% minus the 2-Tail Significance is the level of confidence that the parameter estimate is valid and as stated, considering deviations both above and below the parameter estimate.

The Probability(F-Statistic) describes the ability of the independent variables as a whole in explaining the dependent variable (22:9-4). Again zero is the strongest evidence of explanatory power. The $R^2$ statistic describes the percent of variation in the dependent variable explained by the independent variables (22:9-5). Adjusted $R^2$ is the $R^2$ adjusted so that this model may be compared to others with the same or a greater number of independent variables (22:9-5).

Factors considered for possible inclusion as explanatory variables in a linear regression model were GNP, GDP, oil export revenue, and aggregate military force size. As mentioned in Chapter II, GNP and GDP have been used in previous macroeconomic models. Oil export revenue was also considered since it is a key element of the Saudi Arabian economy for the years under consideration, 1974 to 1992. The aggregate military force size was considered as a possible measure of perceived threat. In other words, a country may tend to base the size of its military on the size of the threat perceived by its leaders.

The linear regression model, using combinations of the possible explanatory variables already mentioned, which

resulted in the lowest RMSE, was one which used gross domestic product in billions of dollars lagged by three years ($GDP_{t-3}$) and current force size in thousands of people (Force). Force size was used primarily to capture the changes in military expenditures which occurred as a result of the Gulf War. The model can be described as follows for year t:

$$E(ME_t) = ß_0 + ß_1(GDP_{t-3}) + ß_2(Force_t)$$

| Variable | Value | T-Statistic | 2-Tail Significance |
|---|---|---|---|
| $ß_0$ | -7.8787415 | -3.36 | 0.0040 |
| $ß_1$ | 0.1490435 | 5.95 | 0.0000 |
| $ß_2$ | 0.1455500 | 9.23 | 0.0000 |

Probability(F-Statistic) = 0.000000

Table 4 presents the actual and forecasted military expenditures found as a result of this model for the years 1974 to 1992 in billions of 1990 dollars.

**Table 4**

Linear Regression Using $GDP_{t-3}$ and Force
(billions of 1990 dollars)

| **Year** | **1974** | **1975** | **1976** | **1977** | **1978** | **1979** | **1980** | **1981** | **1982** | **1983** |
|---|---|---|---|---|---|---|---|---|---|---|
| **ME** | 5.8 | 11.2 | 15.5 | 13.2 | 14.5 | 14.2 | 12.4 | 13.5 | 19.8 | 22.0 |
| **E(ME)** | 7.6 | 9.9 | 11.9 | 12.3 | 13.2 | 15.3 | 16.0 | 17.3 | 19.0 | 20.4 |

| **Year** | **1984** | **1985** | **1986** | **1987** | **1988** | **1989** | **1990** | **1991** | **1992** |
|---|---|---|---|---|---|---|---|---|---|
| **ME** | 18.9 | 21.2 | 21.0 | 19.1 | 16.6 | 16.5 | 22.9 | 34.9 | 33.0 |
| **E(ME)** | 20.4 | 20.2 | 18.3 | 17.7 | 17.3 | 17.5 | 26.5 | 34.0 | 31.3 |

$R^2$ = 90.52% Adjusted $R^2$ = 89.34%
SSE = 83.41 MSE = 5.21 RMSE = 2.28

$ß_0$ is still the axis intercept (i.e. the value of E(ME), if both $GDP_{t-3}$ and Force were zero). $ß_1$ and $ß_2$ are the amounts

that the associated independent variable contributes to the slope of the regression function.

This model has the lowest RMSE observed in any of the models tested and explains over 90% of the variation in Saudi Arabian military expenditures. This model will henceforth be referred to as Model 1. This model has several limitations. The first limitation is how to treat military spending during the Gulf War. A second limitation is the need to estimate aggregate Saudi Arabian force size to make any forecasts. Another limitation is, for forecasts beyond three years into the future, GDP must be estimated. These limitations were addressed as follows to make forecasts for years beyond 1992.

Forecasting Beyond 1992

Gulf War military spending either marks a process change or an impulse. A process change implies that Gulf War spending levels will continue for future years. An impulse would imply that spending levels return to pre-war levels after the Gulf War. If the Gulf War marks a process change, then Model 1 is most appropriate. If the Gulf War marks an impulse, then the force size variable which describes it in Model 1 can be dropped and the data for 1990 to 1992 can be neglected in the model. In reality, this impulse relates to a post-war force size reduction. If military spending is modeled as an impulse, then it would

rise rapidly before and during the Gulf War, but decline following the Gulf War. A model to describe this situation was created using only GDP lagged by three years for data from 1974 to 1989. This model is labeled Model 2. Note that if it were included, force size is relatively constant over this period of time and adds no explanatory power to this model. This model can be described as follows for year t:

$$E(ME_t) = \Gamma_0 + \Gamma_1(GDP_{t-3})$$

| Variable | Value | T-Statistic | 2-Tail Significance |
|---|---|---|---|
| $\Gamma_0$ | 2.6726725 | 1.36 | 0.1946 |
| $\Gamma_1$ | 0.1605499 | 7.03 | 0.0000 |

Probability(F-Statistic) = 0.000006

Table 5 presents the actual and forecasted military expenditures found as a result of this model for the years 1974 to 1989 in billions of 1990 dollars.

**Table 5**

Linear Regression Using Only $GDP_{t-3}$
(billions of 1990 dollars)

| **Year** | **1974** | **1975** | **1976** | **1977** | **1978** | **1979** | **1980** | **1981** | **1982** | **1983** |
|---|---|---|---|---|---|---|---|---|---|---|
| **ME** | 5.8 | 11.2 | 15.5 | 13.2 | 14.5 | 14.2 | 12.4 | 13.5 | 19.8 | 22.0 |
| **E(ME)** | 7.6 | 10.1 | 12.2 | 12.7 | 13.6 | 15.2 | 16.0 | 17.4 | 19.1 | 20.6 |

| **Year** | **1984** | **1985** | **1986** | **1987** | **1988** | **1989** |
|---|---|---|---|---|---|---|
| **ME** | 18.9 | 21.2 | 21.0 | 19.1 | 16.6 | 16.5 |
| **E(ME)** | 20.6 | 20.4 | 18.3 | 17.7 | 16.7 | 17.1 |

$R^2$ = 77.93% Adjusted $R^2$ = 76.35%
SSE = 62.01 MSE = 4.43 RMSE = 2.10

This model explains about 78% of the variation in Saudi Arabian military expenditures. To determine whether Gulf War spending was a process change or an impulse, it is necessary to continue monitoring Saudi Arabian military expenditures; however, post-war downsizing is not an uncommon historical phenomena (9:259-261; 29:57; 40:133) and given the Saudi Arabian economic prospects described in Chapter II, force downsizing is a very real possibility. Both cases will continue to be considered for the sake of completeness.

If the Gulf War is to be considered a process change, it is necessary to forecast Saudi Arabia's force size for the same years it is desired to forecast military expenditures. Historically, Saudi Arabian force size was relatively constant until the Gulf War. Several of the forecasting techniques already mentioned in this chapter were considered in numerous forms for building a model to forecast Saudi Arabian force size.

The model with the lowest RMSE for forecasting Saudi Arabian force size was a naive forecast. The implication of a naive forecasting model out performing other more advanced techniques means that there is little information following the Gulf War on which to base forecasts. This is due primarily to the fact that the Saudi Arabian military force size was relatively constant from 1974 to 1989, as can be

seen in Table 6. This model can be described as follows for year t:

$$E(Force_t) = Force_{t-1}$$

Table 6 presents the actual and forecasted force size found as a result of this model for the years 1974 to 1992 in thousands of people.

**Table 6**

Forecasts for Force Size
(thousands of people)

| **Year** | **1974** | **1975** | **1976** | **1977** | **1978** | **1979** | **1980** | **1981** | **1982** | **1983** |
|---|---|---|---|---|---|---|---|---|---|---|
| **Force** | 75 | 75 | 75 | 75 | 75 | 79 | 79 | 79 | 80 | 80 |
| **E(Force)** | 75 | 75 | 75 | 75 | 75 | 75 | 79 | 79 | 79 | 80 |

| **Year** | **1984** | **1985** | **1986** | **1987** | **1988** | **1989** | **1990** | **1991** | **1992** |
|---|---|---|---|---|---|---|---|---|---|
| **Force** | 80 | 80 | 80 | 80 | 84 | 82 | 146 | 191 | 172 |
| **E(Force)** | 80 | 80 | 80 | 80 | 80 | 84 | 82 | 146 | 191 |

SSE = 6519 MSE = 343.11 RMSE = 18.52

Whether the Gulf War is considered a process change or an impulse in military expenditures, to forecast beyond three years using either Model 1 or Model 2, it is necessary to also forecast GDP. Note that using forecasted values of force size and/or GDP to forecast military expenditures greatly increases the possibility for error and actual values should be used whenever possible. Again, several of the forecasting techniques already mentioned in this chapter were considered in numerous forms for building a model to forecast Saudi Arabian GDP.

The model with the lowest RMSE to describe GDP in billions of 1990 dollars from 1974 to 1992 was Holt-Winters

Exponential Smoothing with additive cycles (22:18-14) with a cycle of three years in length. This model can be described as follows (32:104-106):

Overall smoothing:

$$S_t = \alpha(GDP_t/I_{t-1}) + (1-\alpha)(S_{t-1} + b_{t-1})$$

Trend smoothing:

$$b_t = \Gamma(S_t - S_{t-1}) + (1 - \Gamma)b_{t-1}$$

Seasonal smoothing:

$$I_t = \beta(GDP_t/S_t) + (1 - \beta)I_{t-L}$$

Forecast:

$$E(GDP_{t+m}) = S_t + b_t(m) + I_{t-L+m}$$

where L, S, b, I, $\alpha$, $\beta$, and $\Gamma$ all have the same definitions used previously and $E(GDP_{t+m})$ is the forecast for m years ahead made at time t. Parameters were selected using the same method as described previously. Using the following parameters, this model had the stated results:

| Parameters: | End of period levels: | | |
|---|---|---|---|
| $\alpha$ = 0.83 | Mean ($S_{1992}$) | | 118.0560 |
| $\beta$ = 1.00 | Trend ($b_{1992}$) | | 5.207211 |
| $\Gamma$ = 0.00 | Cycle ($I_t$) | 1990 | -0.609272 |
| | | 1991 | 1.986552 |
| L = 3 years | | 1992 | -1.377280 |

Table 7 presents the actual and forecasted GDP found as a result of this model for the years 1974 to 1992 in billions of 1990 dollars. For a more rigorous description of how these forecasts were calculated using end of period levels, see Appendix C.

**Table 7**

Forecasts for GDP
(billions of 1990 dollars)

| **Year** | **1974** | **1975** | **1976** | **1977** | **1978** | **1979** | **1980** | **1981** | **1982** | **1983** |
|---|---|---|---|---|---|---|---|---|---|---|
| **GDP** | 62 | 68 | 78 | 83 | 92 | 102 | 112 | 112 | 110 | 97 |
| **E(GDP)** | 66 | 63 | 74 | 82 | 92 | 103 | 107 | 123 | 118 | 103 |

| **Year** | **1984** | **1985** | **1986** | **1987** | **1988** | **1989** | **1990** | **1991** | **1992** |
|---|---|---|---|---|---|---|---|---|---|
| **GDP** | 93 | 87 | 90 | 88 | 94 | 95 | 105 | 115 | 116 |
| **E(GDP)** | 90 | 89 | 76 | 92 | 91 | 93 | 99 | 115 | 120 |

SSE = 610.76 MSE = 32.15 RMSE = 5.67

<u>Summary</u>

Based on graphical analysis, RMSE, and explanatory power, the models chosen for further study in this report are the linear regression models which consider the Gulf War as a process change, Model 1, and as an impulse, Model 2. The results of these models are depicted in Figure 1. It is important to note that these selected models not only have the smallest RMSE, but have significant explanatory power which was described in Chapter II as a desirable characteristic for any model used in this study.

Table 8 shows all of the models for military expenditures discussed in this chapter; they are ranked by RMSE. It is necessary to verify that the selected models comply with the assumptions of the associated technique and to bound the error of forecasts. This is the emphasis of Chapter IV. The cycling and trends detected in the exponential smoothing models should be monitored as more data become available.

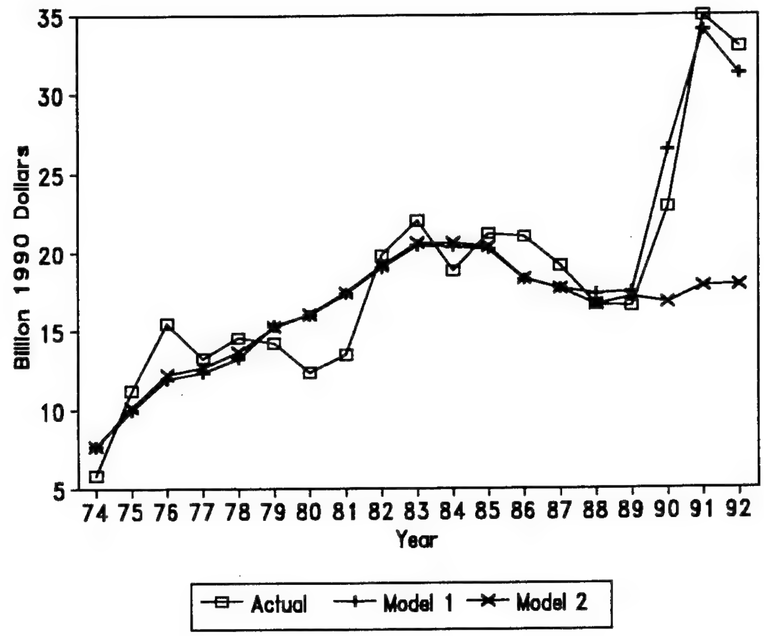


**Figure 1.** Saudi Arabian Military Expenditures

**Table 8**

Models for Military Expenditures

| **Rank** | **Model** | **SSE** | **MSE** | **RMSE** |
|---|---|---|---|---|
| 1 | Model 2* | 62.01 | 4.43 | 2.10 |
| 2 | Model 1 | 83.41 | 5.21 | 2.28 |
| 3 | Holt-Winters | 106.34 | 5.60 | 2.37 |
| 4 | Naive Forecast | 317.10 | 16.69 | 4.09 |
| 5 | Simple Regression | 297.42 | 17.47 | 4.18 |

* Recall that Model 2 is based on a smaller sample size than the other models listed. Although this discounts SSE; Model 2 still has a smaller MSE and RMSE which takes sample size and degrees of freedom into account.

# IV. Model Analysis

When using linear regression, it is necessary to comply with the assumptions of the technique. Assumptions of linear regression models are: (1) the error between actual values and forecasts is zero, (2) the variance of these errors is constant, (3) errors are not autocorrelated, (4) explanatory variables are either nonstochastic or, if stochastic, distributed independently from the distribution of the errors, (5) there is no multicollinearity among explanatory variables, (6) the errors are normally distributed with the mean and variance described in (1) and (2), and (7) the regression model is correctly specified (21:279-280).

Three common violations of these assumptions which must be tested for are multicollinearity, heteroscedasticity, and autocorrelation (21:282). Autocorrelation analysis considers violations of assumptions listed above as one, three, and six. Heteroschedastic analysis considers assumption two above. Multicollinearity analysis considers assumption five above. Both of the linear regression models for Saudi Arabian military expenditures described in the last chapter were tested for these violations. The results of this testing are described in this chapter, along with a discussion of prediction intervals for the respective forecasts.

Note that, as discussed in Chapters II and III, the models are correctly specified by using explanatory variables that have a theoretically logical relationship to military expenditures. Thus, assumption seven is satisfied. With respect to assumption four, explanatory variables are nonstochastic until estimates are required for forecasting; then they are stochastic as described in Chapter III. Their distributions are discussed and presented in terms of prediction intervals.

Multicollinearity

Multicollinearity is the existence of a linear relationship between explanatory variables used in a regression model (21:283). Models with multicollinearity usually have a high $R^2$, but insignificant T-statistics (21:299). Another sign of multicollinearity is high pairwise correlations among the explanatory variables, where high is defined as greater than 80% (21:299). Note that multicollinearity can only exist when there is more than one explanatory variable. Thus, the model for military expenditures which treats the Gulf War as an impulse (Model 2) and uses only $GDP_{t-3}$ as an explanatory variable, definitely cannot have multicollinearity. The model which uses both $GDP_{t-3}$ and force size (Model 1) has a high $R^2$ and significant T-statistics for both explanatory variables. The correlation between $GDP_{t-3}$ and force size is only

22.31%. Therefore, there is not enough evidence to state that Model 1 has multicollinearity.

Heteroscedasticity

Heteroscedasticity means that errors in the regression model do not have constant variance (21:316). The first step in discovering heteroscedasticity is to look at graphs of the squared residuals versus the forecasts (21:327-328). Graphs of the squared residuals versus the explanatory variables should also be examined (21:327-328). If these graphs show a pattern, then heteroscedasticity may exist (21:328). Any systematic pattern such as increasing, decreasing, level, or parabolic would be reason to suspect heteroscedasticity (21:328). This was done for the residuals, forecasts, and explanatory variables in both of the models under consideration. Figures 2, 3, and 4 are for Model 1. Figures 5 and 6 are for Model 2. None of these graphs indicates any particular pattern.

Heteroscedasticity can also be detected by the use of the White Heteroscedasticity Test (22:15-14). An insignificant test statistic implies that the test is negative for heteroscedasticity (22:15-15). Results of this test for Models 1 and 2 are presented in Table 9. This test and the graphical analysis both indicate that neither of these models has heteroscedasticity problems.

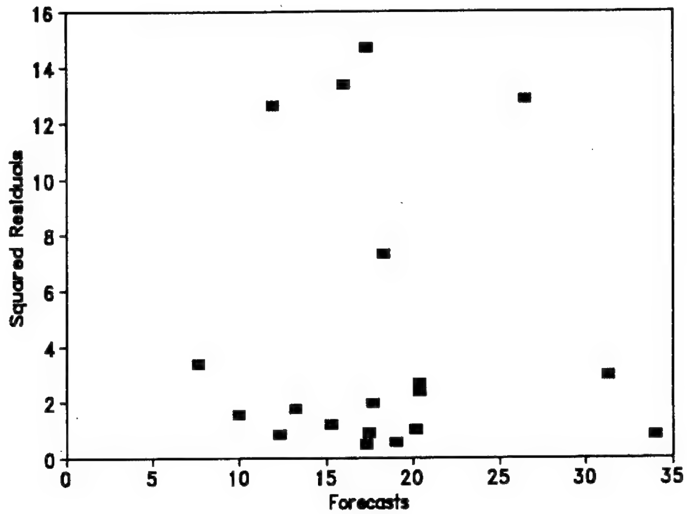


**Figure 2.** Squared Residuals for Model 1 Versus Forecasts

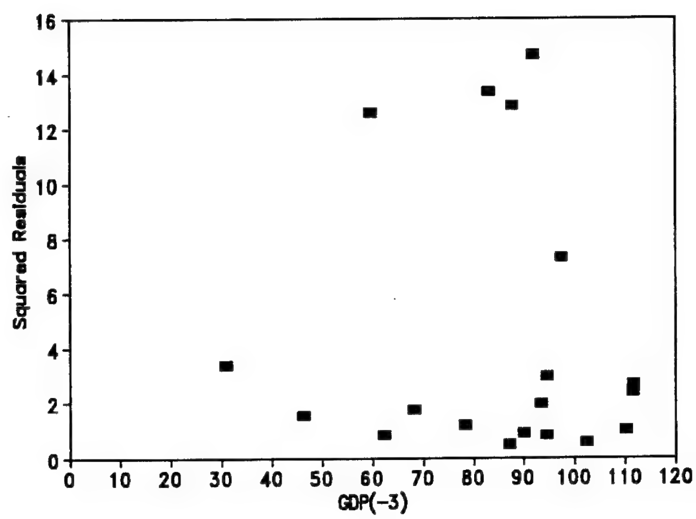


**Figure 3.** Squared Residuals for Model 1 Versus $GDP_{t-3}$

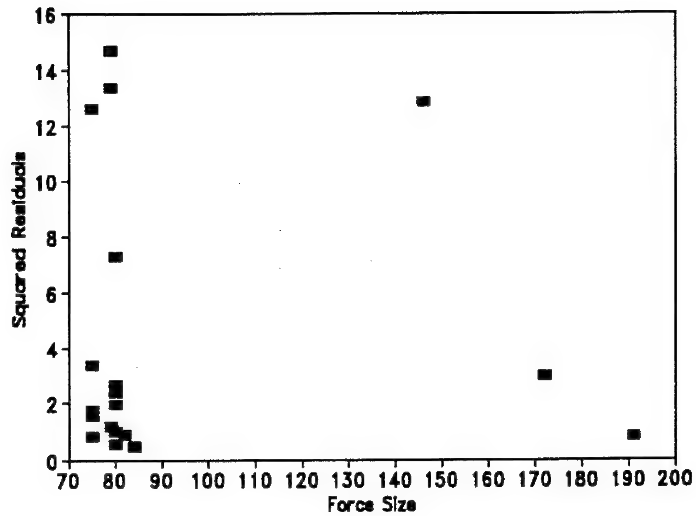


**Figure 4.** Squared Residuals for Model 1 Versus Force Size

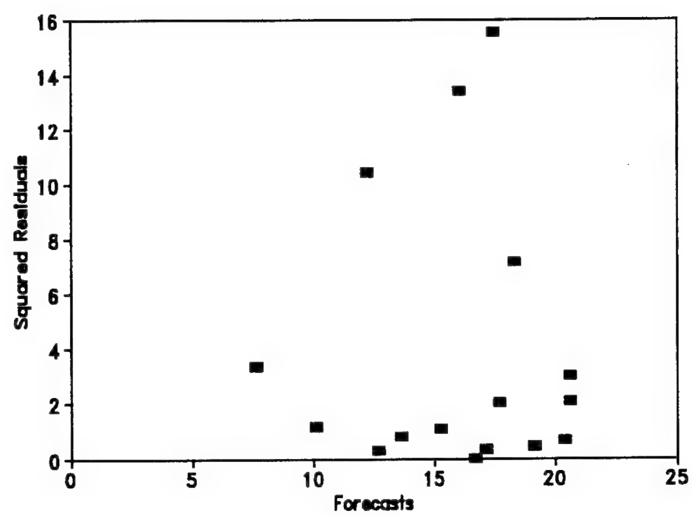


**Figure 5.** Squared Residuals for Model 2 Versus Forecasts

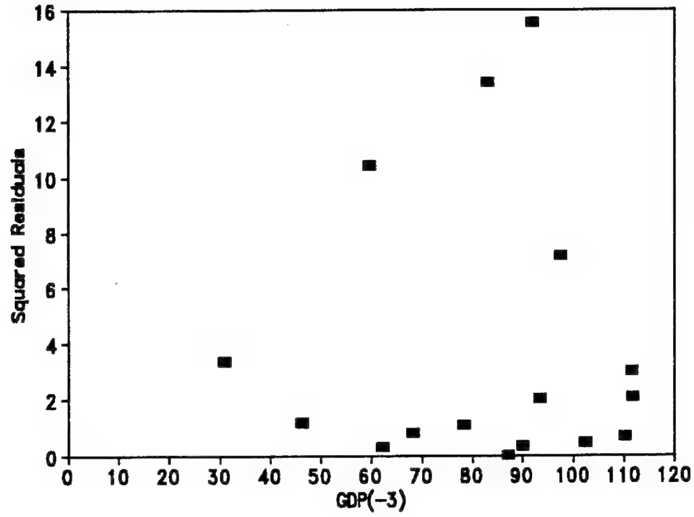


**Figure 6.** Squared Residuals for Model 2 Versus $GDP_{t-3}$

**Table 9**

Heteroscedasticity Tests

| **Model** | **F-Statistic** | **Probability** | **Conclusion** |
|---|---|---|---|
| **Model 1** | 0.7359 | 0.5827 | Negative |
| **Model 2** | 0.2727 | 0.7656 | Negative |

Autocorrelation

Autocorrelation exists when observations ordered in time are correlated to each other (21:353). A method used to detect autocorrelation is to graph the residuals of a linear regression model against time (21:369). Residuals should be normally disturbed about zero and exhibit no particular pattern (21:370). This was done for Models 1 and 2. Figure 7 is for Model 1. Figure 8 is for Model 2. Both graphs appear to be normally distributed around zero and neither shows any patterns.

It is also possible to test for autocorrelation using a Box-Pierce Q-Statistic (22:14-4). This test examines the normality of the error distribution using lagged correlations between errors in different time periods (41:505). An insignificant test statistic implies that autocorrelation over any tested lags probably does not exist. Results for errors in the models under consideration can be found in Table 10. This test and the graphical analysis both indicate that the errors are not autocorrelated.

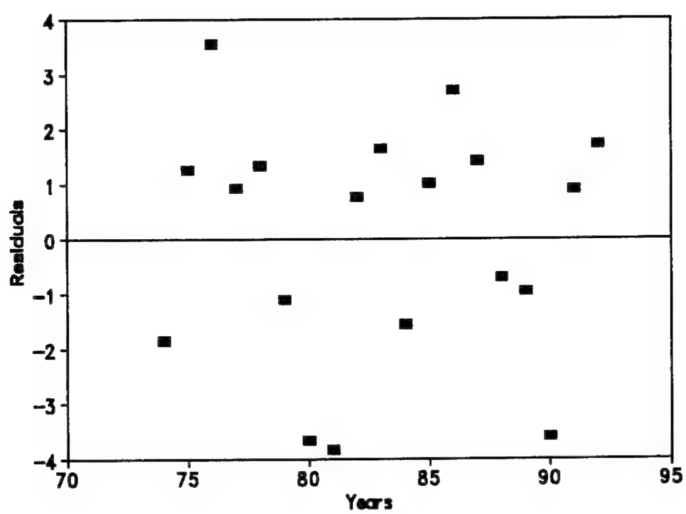


**Figure 7.** Residuals for Model 1 Versus Time

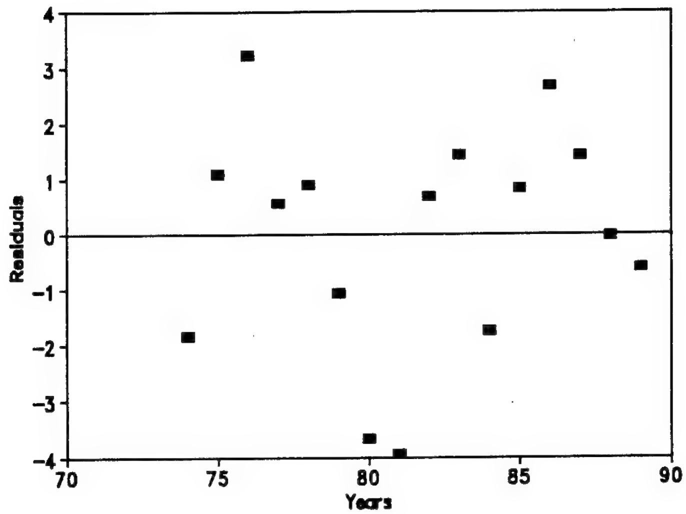


**Figure 8.** Residuals for Model 2 Versus Time

**Table 10**

Autocorrelation Tests

| Model | Q-Statistic* | Probability | Conclusion |
|---|---|---|---|
| **Model 1** | 11.76 | 0.4649 | Negative |
| **Model 2** | 7.70 | 0.8083 | Negative |

* Lags of up to 12 years were tested.

Although these tests indicate that the distribution of the errors are not significantly different from a normal distribution, it should be noted that both models exhibited a slightly negative skewness. This implies that these models are slightly conservative in their estimates of Saudi Arabian military expenditures. Table 11 presents the skewness and kurtosis of Models 1 and 2.

**Table 11**

Skewness and Kurtosis of Tested Models

| Model | Skewness | Kurtosis |
|---|---|---|
| **Model 1** | -0.4428 | 2.119 |
| **Model 2** | -0.4868 | 2.399 |

(Note: a normal distribution has a zero skewness and kurtosis of three.)

Prediction Intervals

For this analysis to be complete, prediction intervals were calculated for the values forecasted by these models. The 95% prediction interval for Model 1 is depicted in Figure 9. Figure 10 shows the 95% prediction interval for Model 2. These intervals are defined as follows (41:187):

$$E(ME) \pm t_{\alpha/2}(S_f)$$

$\alpha=.05$ For Model 1, $t_{\alpha/2} \approx 2.120$ (21:677)
For Model 2, $t_{\alpha/2} \approx 2.145$ (21:677)

For forecasts made during the observed periods (41:186,200):

$$S_f^2 = MSE(1+\mathbf{X}_h(\mathbf{X}^T\mathbf{X})^{-1}\mathbf{X}_h^T)$$

Where $\mathbf{X}$ is a matrix consisting of [$\mathbf{1}$ $GDP_{t-3}$ $Force_t$] for Model 1 and [$\mathbf{1}$ $GDP_{t-3}$] for Model 2. $\mathbf{1}$ is a column vector of 1's and t includes all of the observed periods. $\mathbf{X}_h$ is the vector of values for a given year, t = h (i.e. $\mathbf{X}_h$ is equivalent to a row of the $\mathbf{X}$ matrix). For forecasts beyond the observed periods, the following procedure was used (41:197-198):

1. The 95% prediction interval that would be obtained if the estimated explanatory variable(s) had been two standard errors higher or lower was calculated.

2. The 95% prediction interval was then taken to be the union of these two prediction intervals.

This procedure is necessary to account for the additional error involved due to using estimates of the explanatory variables (41:195-198).

Prediction intervals provide a margin of error around point forecasts (41:180). The prediction intervals depicted in Figures 9 and 10 show the region in which the actual values are expected to lie with a probability of 95% for a given year. Within these prediction intervals lies the point forecast produced using Model 1 and 2, respectively.

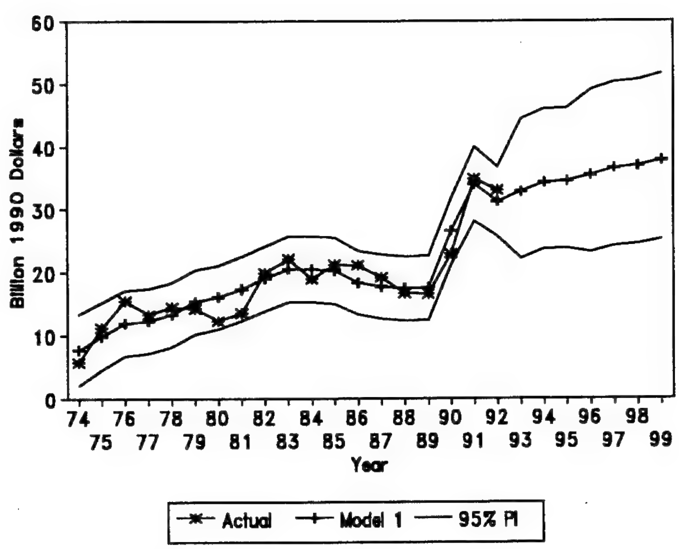


**Figure 9.** Forecasts with Prediction Intervals for Model 1

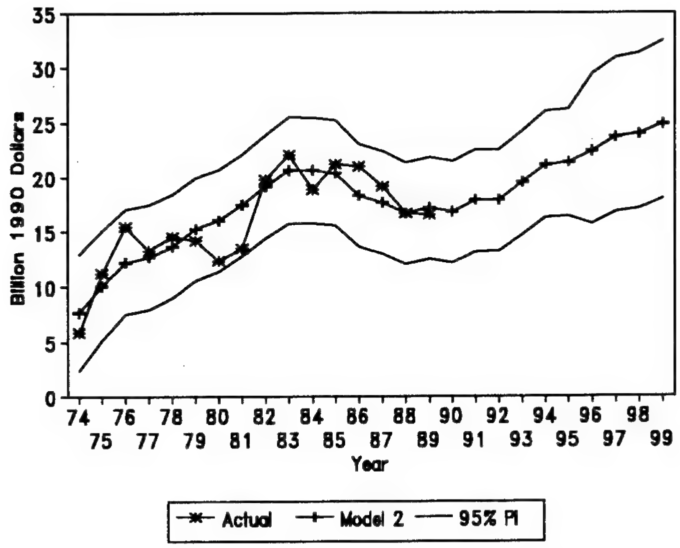


**Figure 10.** Forecasts with Prediction Intervals for Model 2

It is important to note that, as described by these intervals, forecasts have significant potential for error. As shown in Figures 9 and 10, the possibility for error increases with time. This possibility of error by no means implies that the forecasts should not be used. It simply means that when using these forecasts in any application, it is necessary to remain aware of the potential error. Chapter V addresses some practical applications of these forecasts.

# V. Applications

As discussed in Chapters I and II, a goal of this study is to determine the effect of changes in Saudi Arabian military expenditures on the U.S. industrial base. In Chapters III and IV, two models for Saudi Arabian military expenditures were developed and analyzed. In this chapter, the forecasts produced by these models are used as input for applications which relate changes in Saudi Arabian military expenditures to the effect on the U.S. industrial base. These applications involve many of the factors discussed in Chapter II, such as succession of the Saudi Arabian King, U.S. Congress, U.S. foreign military sales (FMS) to Saudi Arabia, and uncertainty regarding future Saudi Arabian military expenditures.

## Sample Problem

Consider, for example, the question of: "Which estimate of the Royal Saudi Air Force (RSAF) budget should SAF/IAS use when recommending a cutoff line for U.S. Foreign Military Sales to the RSAF?" To answer this question, a decision must be made. This decision involves uncertainty with respect to the amount of money the RSAF can devote to defense purchases from foreign countries, the RSAF preference for U.S. goods, and how much of the goods requested by the RSAF will be approved for sale by the U.S.

Congress. The decision of where to apply this cutoff line for sales is one made by U.S. decision makers. In other words, this cutoff line is the recommended ceiling for U.S. foreign military sales to the RSAF. Therefore, this cutoff line decision is directly related to the risk preference of U.S. decision makers.

The decision maker could be risk averse, risk neutral, or risk seeking. A risk averse decision maker is one who is willing to accept an alternative with a lower expected value in the future, if it has less uncertainty than the other alternatives (10:367-368). A risk neutral decision maker makes decisions based only on the expected value of an alternative (10:367-368). A risk seeking decision maker is one who is willing to pursue an alternative with greater uncertainty, even if it has a lower expected value in the future than other alternatives (10:367-368).

Assume that the decision maker has two alternatives. The first is to base the cutoff line decision on a budget projected for foreign military purchases by the RSAF and the second alternative is to base the decision on some other estimate. Since these purchases by the RSAF will be some subset of total military expenditures, sources on which to base the second alternative are estimates from the models discussed in Chapters III and IV of this study.

Negative consequences of selecting either alternative and establishing an incorrect cutoff line are overselling,

which would result in default or debt restructuring (49:46; 38:22), and underselling which represents lost opportunity. No matter which alternative is selected, RSAF purchases will be made from the U.S. or from another country. If goods are purchased from the U.S., the American industrial base benefits. If goods are purchased elsewhere, then American industry has lost the benefits of this opportunity.

This cutoff line decision is exactly the type which decision analysis is designed to address (10:2-3). The decision of how much to sell to the RSAF in a given year is an irrevocable allocation of resources for those goods which are actually sold to the RSAF. In other words, once items are sold to the RSAF, the U.S. cannot realistically ask for them back. Decision analysis is only applicable when a decision involves an irrevocable allocation of resources (10:2-3).

The cutoff line decision involves many factors and uncertainties. The cutoff line decision depends on the decision maker. The decision maker may have multiple objectives including maximizing total sales, maximizing industrial growth, maximizing the creation of new U.S. jobs, and minimizing any risks to U.S. national security and/or the U.S. economy (4:37; 19:5). Different perceptions of the uncertainties and risks involved may result in different courses of action. Decision analysis is best suited for decisions which are complex, uncertain, and may have

multiple objectives, and where different perspectives lead to different conclusions (10:2-3).

Before jumping directly into building a decision analysis model, it is necessary to gain an understanding of what to model (10:9). A model should include all essential elements needed to solve the problem (10:7-8). Assumptions of the model used to solve the example RSAF FMS cutoff line decision problem are as follows:

Succession of the king

The king dictates the preference for U.S. goods. Future kings may have different preferences for U.S. goods. Kings are modeled based on their preference for U.S. goods. A type 20 king always prefers U.S. goods. Types between 0 and 20 represent 5% changes in preference. A type 0 king has no preference for U.S. goods.

FMS package requests

Items the RSAF desires to purchase from the U.S. are modeled as FMS package requests which may include one or more weapon systems and related service and support. FMS package requests will involve some percent of new production and some percent of sales from shelf stock items. Both shelf stock sales (labeled stock sales in the remainder of this study) and new production will increase income to the U.S., but only new production promotes growth in the industrial base. U.S. jobs are directly tied to new production (4:37). The maximum value for FMS sales to the

RSAF considering the U.S. cutoff line, the Saudi Arabian preference for U.S. goods, and uncertainty about the actual amount of RSAF FMS is denoted FMS to RSAF.

The U.S. Congress may not approve all FMS package requests. This process will be modeled using the Extended Pearson-Tukey method since it would be nearly impossible to model future behavior of the U.S. Congress down to an exact dollar measure (10:217-218). U.S. Congress may choose to reduce the FMS to RSAF for any number of reasons related to U.S. national interests. The result of Congressional action is the approval of the sale of goods to the RSAF. This value is denoted Final Sale and, as already mentioned, involves some portion of stock sales and some portion of new production. These portions are based on the original request and any changes made prior to the final sale of goods to the RSAF.

U.S. decision making process

Since FMS to the RSAF involves billions of dollars, it is likely that decision makers are risk adverse. Thus, the measure on which to base a decision will be the value of the sale to the U.S. in terms of dollars and the creation of industrial growth bearing in mind concerns for U.S. national interests and security. This is known as the utility of the sale (10:379).

Utility in this decision is the value of the sale to the U.S. Utility was modeled in this example using an

exponential utility function. Exponential utility functions have been found useful in modeling the risk tolerance of large organizations (10:379-382). The utility function used in this example has the form $U(x) = 1 - e^{-x/R}$; where x is value of an FMS program in billions of dollars and R is the risk tolerance (10:379).

Risk tolerance, R, can be considered the largest value that a decision maker would gamble on the given decision (10:379). Since R cannot be negative, utility always lies between zero and one (i.e. $0 \leq U(x) \leq 1$, for all x). For the purpose of this study, utility can be considered unitless. A utility of one is the most desirable and a utility of zero is the least desirable. The convex nature of this function indicates that it is useful in describing risk averse behavior.

Measures of performance

The model used in this chapter makes decisions between alternatives based on the value to the U.S. in terms of utility, subject to weighted values of stock sales and new production and the risk tolerance already mentioned. The equation for value to the U.S. has the form:

$$\text{RSAF FMS Value to U.S.} = (w)(1-e^{-(\text{New Production})/R}) + (1-w)(1-e^{-(\text{Stock Sales})/R})$$

where w is a weight which can be used to emphasize new production or stock sales. The weight, w, must lie between zero and one. A weight of exactly 0.5 places equal weight

on new production and stock sales. As the weight, w, increases from 0.5 to 1 more emphasis is placed on new production. As w decreases from 0.5 to 0, more emphasis is placed on stock sales. The objective of the decision model is to maximize utility represented by RSAF FMS value to the U.S.

It is possible to represent these relationships in an influence diagram (10:34-49). As mentioned in Chapter II, an influence diagram is a graphical representation of a decision problem (10:34). The influence diagram for the RSAF decision model is depicted in Figure 11. In this figure, rectangles represent decisions, rectangles with rounded edges represent known values or equations, and ovals represent uncertainties (10:34). Arrows depict influence (10:36-37). This influence can represent timing or some specific probabilistic relevance (10:36). For example, the arrow between the "Risk Tolerance" node and the "Which estimate?" decision node implies that the risk tolerance must be defined prior to evaluating the decision. The "Actual RSAF FMS" budget can be higher, lower, or close to the "FMS to RSAF", so there is an arrow indicating this probabilistic relationship.

Prior to running this model and determining which alternative has the greatest value to the U.S., it is necessary to define certain initial conditions. Initial conditions differ from assumptions.

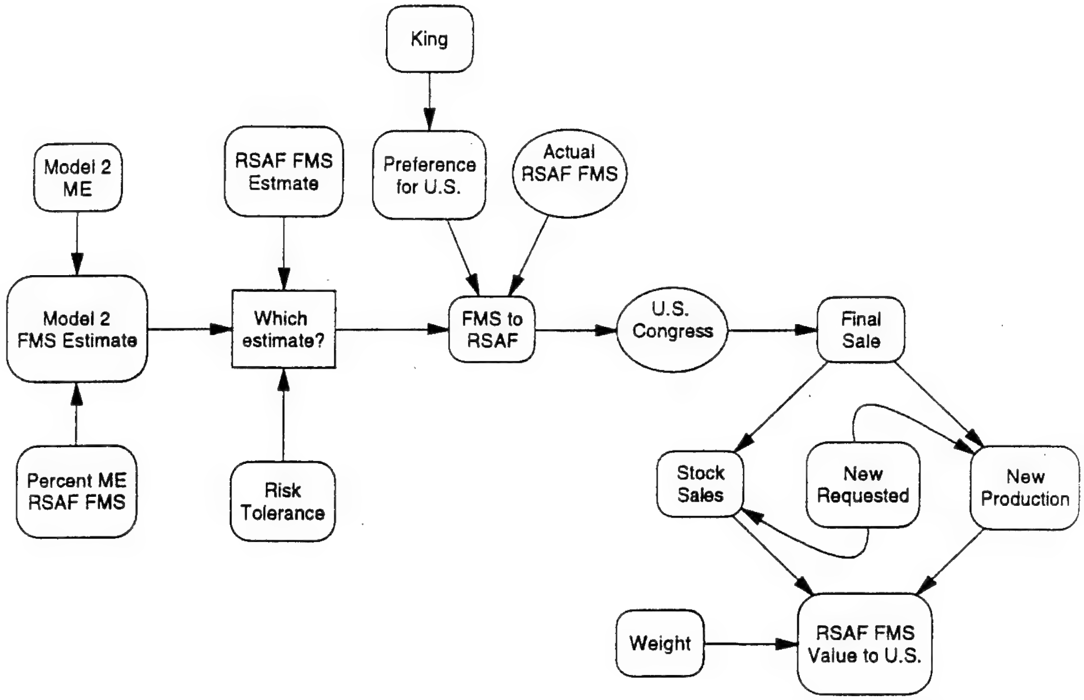


**Figure 11.** Influence Diagram for the RSAF FMS Decision

Initial conditions are easily changed from one run to the next, but assumptions are part of the model structure (10:8). Results may be significantly influenced by the initial conditions. Initial conditions used <u>for example purposes only</u> were:

- The alternatives are either using the RSAF budget estimate or using an estimate derived from Model 2 for 1996 adjusted to 1996 dollars assuming 3% inflation ($26.7 billion).
- The King always prefers U.S. goods (King type 20).
- The RSAF FMS estimate is $3.25 billion.

- The Model 2 FMS estimate is 11% of the total military expenditures estimated by Model 2 (or $2.937 billion). This is denoted Percent ME RSAF FMS.

- The requested FMS package requires 90% new production (i.e. New Requested).

- It is assumed that the risk tolerance is $1 billion dollars (i.e. Risk Tolerance, R, equals 1). Note that sensitivity analysis will be conducted for a range of possible values of R. Thus, this initial value of R need not be exact, but should be realistic.

- Growth in the U.S. industrial base and U.S. jobs are twice as valuable as other income from FMS sales. Thus, w = 2/3.

- Following the Extended Pearson-Tukey method, assume 18.5% the of time the actual RSAF FMS budget is 30% lower than the RSAF estimate and 5% lower than the Model 2 estimate. 63% of the time the actual RSAF FMS budget is close to the estimates. Close will be considered 80% for the RSAF FMS estimate and exact for the Model 2 estimate. These probabilities and related outcomes take into account the conservative nature of Model 2. As mentioned in Chapters III and IV, Model 2 estimates have a relatively low variance compared to the other models tested and errors are assumed normally distributed with a mean of zero. 18.5% of the time the actual RSAF FMS budget is higher than the estimates.

There is no default in this case, but there is lost sales opportunity.

- 18.5% of the time the U.S. Congress approves the recommended FMS to the RSAF (denoted FMS to RSAF), 63% of the time the U.S. Congress approves 90% of the recommended FMS to the RSAF, and 18.5% of the time the U.S. Congress only approves 80% of the recommended FMS to the RSAF. These probabilities follow the Extended Pearson-Tukey method already mentioned.

Now that the assumptions and initial conditions have been established, it is possible to determine which estimate from the two alternatives provides the greatest value to the U.S. Using the relationships depicted in the influence diagram, the alternative with the greatest value is selected as the solution to the decision of which estimate to use as a cutoff line. For a more detailed description of these calculations refer to Appendix D. Appendix E lists the actual computer code used to run this decision analysis model on the DPL decision analysis software package.

As already discussed, for the RSAF FMS decision the solution is based on maximizing RSAF FMS Value to the U.S. This is the solution which is based on the utility function used in the problem for the specified risk tolerance.

The solution is determined by following the path taken for each alternative through the influence diagram and selecting the alternative which maximizes the RSAF FMS Value

to the U.S. The value for each alternative and solution for the RSAF FMS cutoff line decision is shown in Table 12.

**Table 12**

RSAF FMS Decision Analysis Results

| **Alternative** | **Value** (utility) | **Decision** |
|---|---|---|
| **RSAF FMS Estimate** | .66 | |
| **Model 2 FMS Estimate** | .68 | Use Model 2 FMS Estimate |

Since the RSAF FMS decision analysis model is based on a set of assumptions and initial conditions with which everyone may not agree, it is possible to conduct sensitivity analysis for certain elements while holding all others constant (10:116-119). One way of displaying such an analysis is to use a Tornado Diagram (10:116-119). Such a diagram shows changes in the utility and the decision over a range for a given element of the decision analysis model (10:116-119). These ranges must include, as a baseline, the original solution (10:117). This was done for the RSAF cutoff line decision over the ranges shown in Table 13 and can be seen in Figure 12.

**Table 13**

Tornado Diagram Ranges

| **Factor** | **Base** | **Range** |
|---|---|---|
| Type of King | 20 | 0 to 20 |
| Percent ME RSAF FMS | 11% | 0% to 100% |
| New Requested | 90% | 0% to 100% |
| Risk Tolerance | 1 | .5 to 1.5 |

It can be seen from Figure 12 that the only factors, over the given ranges, which resulted in a change to the decision were the type of king and the percent of total military expenditures devoted to RSAF FMS. That means that these are the factors which are most sensitive in the selection of an alternative. Thus, these are factors which should be given the greatest attention in the future. Figure 12 also indicates that some combination of new production and stock sales are desirable (i.e. 0% New Requested and 100% New Requested both reduce utility).

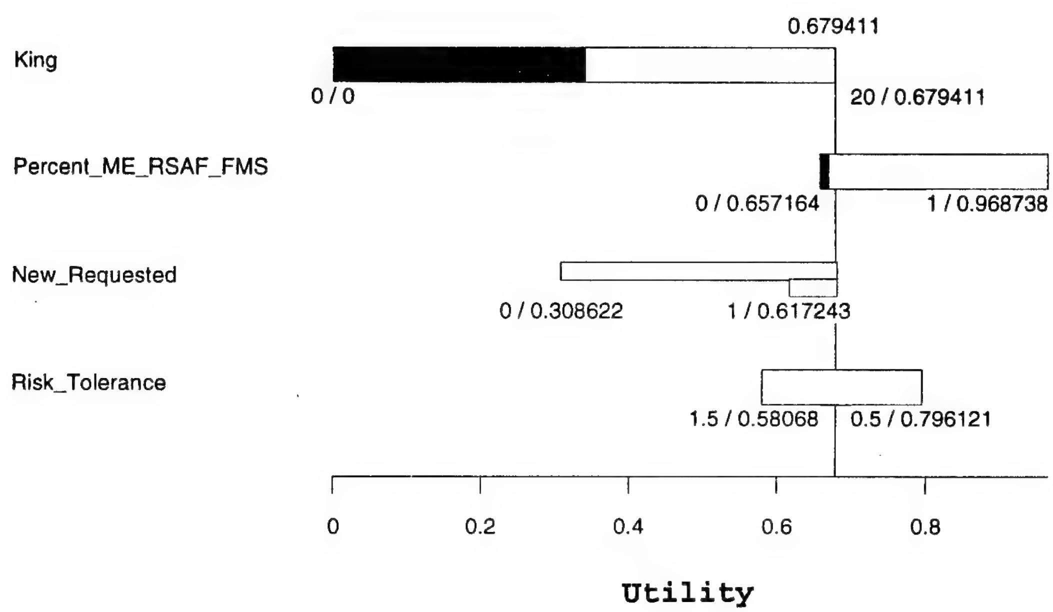


**Figure 12.** RSAF FMS Decision Tornado Diagram

## Other Applications

The example which has been discussed in this chapter is only one application of decision analysis. The model discussed could be used to compare two different foreign military sales programs with different initial conditions against each other. This model could also be used to look at countries other than Saudi Arabia by adjusting the initial conditions such that the decisions of the U.S. Congress now represent national security concerns and uses the type of king as a method of modeling the countries preference for U.S. goods. Overall, decision analysis is a very robust tool for this type of analysis.

## VI. Conclusions and Recommendations

In Chapters I and II, the significance of changes in Saudi Arabian military expenditures to the United States was discussed in detail. In Chapters III and IV, it was demonstrated that it is possible to forecast these changes. In Chapter V, it was further demonstrated that the effect of these changes can be measured in very real terms with respect to the U.S. industrial base.

Figure 13 and Figure 14 show the forecasted Saudi Arabian military expenditures for the years 1993 to 1999. Figure 13 shows a forecast using Model 1 and Figure 14 shows a forecast using Model 2. Note the difference in magnitude of the forecasts by the two models. It is recommended that as long as it can be assumed that a war of the magnitude of the Gulf War is not imminent, that Model 2 be used as the best forecast for Saudi Arabian military expenditures. Although, as discussed in Chapter IV and as demonstrated by the prediction intervals, it is somewhat precarious to make these extrapolations.

Model 2, which is based on the assumption of post-war downsizing, is also recommended for use because it has the lowest RMSE of all the models tested and has as a smaller variance than Model 1, as described by their respective prediction intervals. Models 1 and 2 both have significant explanatory power; however, Model 2 requires a smaller

database since it only uses one explanatory variable. Both explanatory power and smaller database requirements were cited as advantageous characteristics of a model in Chapter II.

The year 1999 is the end of Saudi Arabia's Sixth Development Plan (44:8), so it is logical to assume that the process observed in previous years will remain in use to at least 1999. Note that these models can be used to forecast an infinite number of years into the future; however, possible error also drastically increases with time.

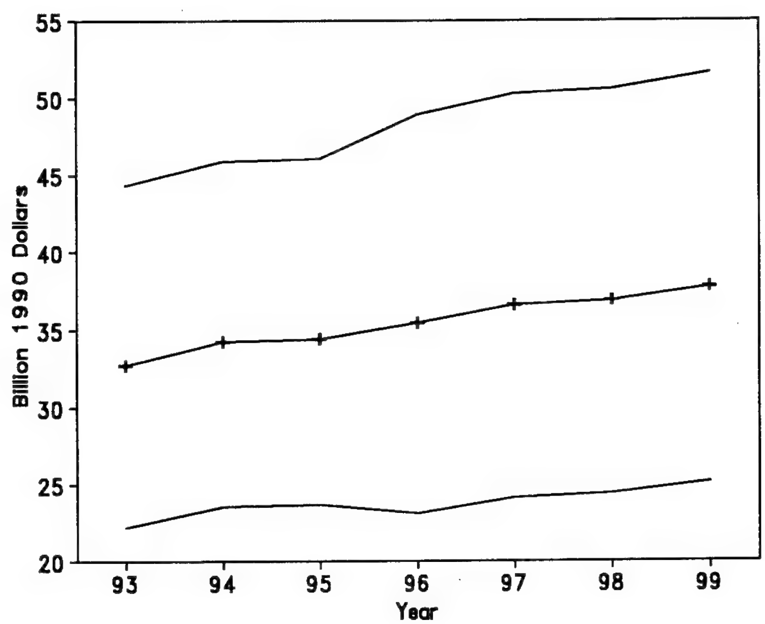


**Figure 13.** Forecasts for Saudi Arabian ME (Model 1)

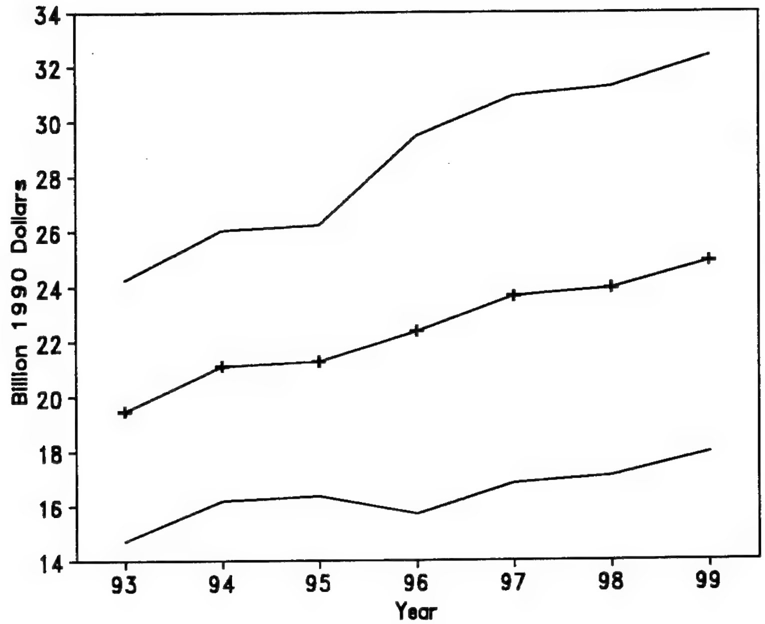


**Figure 14.** Forecasts for Saudi Arabian ME (Model 2)

In Chapter III, it was noted that a three year cycle seemed present in Saudi Arabia's GDP and an eight year cycle seemed present in Saudi Arabia's military expenditures. It is recommended that as more data become available, these cycles be further investigated. It is also recommended that all of the models be updated with the most recent data available prior to use.

In Chapter V, some applications of these models were discussed. It is recommended that further uses be investigated. As this work was at its core a case study, it is recommended that extensions to other countries be attempted. Countries which are heavily involved in arms purchases would seem the most likely candidates.

Overall, changes in the Saudi Arabian economy do affect military spending. This effect can be measured and forecasted. These changes do influence the U.S. industrial base. This effect can also be measured and forecasted. However, these forecasts are subject to error and unforeseen events. For the decision analysis model, these forecasts are also subject to the truth of the assumptions and initial conditions used in any one application.

# Appendix A: Data Tables

| Label | Description<br>(all values in billions of 1990 dollars unless otherwise noted) |
|---|---|
| A | Saudi Arabian military expenditures<br>(billions of current year dollars) |
| B* | Saudi Arabian military expenditures (ME) |
| C | Naive forecasts for ME |
| D | Holt-Winters forecasts for ME |
| E | Simple linear regression forecasts for ME |
| F | Model 1 forecasts for ME |
| G | Upper 95% prediction intervals for Model 1 |
| H | Lower 95% prediction intervals for Model 1 |
| I | Model 2 forecasts for ME |
| J | Upper 95% prediction intervals for Model 2 |
| K | Lower 95% prediction intervals for Model 2 |
| L | Saudi Arabian GNP<br>(millions of current year dollars) |
| M | Saudi Arabian GNP |
| N | Saudi Arabian GDP<br>(billions of current year riyals) |
| O | Saudi Arabian GDP |
| P | Holt-Winters forecasts for GDP |
| Q | Oil export revenue<br>(billions of current year riyals) |
| R | Oil export revenue |
| S | Force size<br>(thousands of people) |
| T | Naive forecast for force size<br>(thousands of people) |
| U | Exchange rate<br>(riyals/dollar, annual average) |
| V | Saudi Arabian GDP deflation factor<br>(percent, base year 1990) |

* The formula used to convert column A values to the values in column B is $B = A/(V/100)$.

| Year | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| 1970 | 1.531 | 10.66899 | | | | |
| 1971 | 1.625 | 9.62678 | | | | |
| 1972 | 2.186 | 14.82034 | | | | |
| 1973 | 2.891 | 15.72050 | | | | |
| 1974 | 2.606 | 5.80142 | 5.80143 | 8.57517 | 9.11686 | 7.64634 |
| 1975 | 6.360 | 11.18340 | 5.80142 | 11.93792 | 10.12794 | 9.92704 |
| 1976 | 9.196 | 15.45287 | 11.18340 | 13.16182 | 11.13901 | 11.90389 |
| 1977 | 9.273 | 13.24714 | 15.45287 | 13.01465 | 12.15008 | 12.32037 |
| 1978 | 10.490 | 14.54319 | 13.24714 | 13.73371 | 13.16115 | 13.21484 |
| 1979 | 13.490 | 14.20000 | 14.54319 | 13.11982 | 14.17222 | 15.29300 |
| 1980 | 16.330 | 12.35156 | 14.20000 | 11.57244 | 15.18329 | 16.00552 |
| 1981 | 20.050 | 13.48806 | 12.35156 | 12.23901 | 16.19436 | 17.31979 |
| 1982 | 24.010 | 19.78411 | 13.48806 | 14.69503 | 17.20543 | 19.02504 |
| 1983 | 24.480 | 22.03619 | 19.78411 | 20.44492 | 18.21650 | 20.40182 |
| 1984 | 20.130 | 18.85184 | 22.03619 | 22.28345 | 19.22757 | 20.39868 |
| 1985 | 21.060 | 21.18286 | 18.85184 | 21.40061 | 20.23864 | 20.17685 |
| 1986 | 17.070 | 20.98857 | 21.18286 | 22.16981 | 21.24971 | 18.28462 |
| 1987 | 16.000 | 19.09536 | 20.98857 | 20.73823 | 22.26078 | 17.68445 |
| 1988 | 13.420 | 16.64187 | 19.09536 | 17.86750 | 23.27185 | 17.34094 |
| 1989 | 14.500 | 16.52422 | 16.64187 | 18.46156 | 24.28292 | 17.47124 |
| 1990 | 22.870 | 22.87000 | 16.52422 | 21.56956 | 25.29399 | 26.45469 |
| 1991 | 35.050 | 34.89646 | 22.87000 | 29.04855 | 26.30506 | 33.99422 |
| 1992 | 34.550 | 32.97700 | 34.89646 | 31.16206 | 27.31614 | 31.25274 |
| 1993 | | | | | | 32.75628 |
| 1994 | | | | | | 34.27011 |
| 1995 | | | | | | 34.44445 |
| 1996 | | | | | | 35.43663 |
| 1997 | | | | | | 36.59963 |
| 1998 | | | | | | 36.87437 |
| 1999 | | | | | | 37.76494 |

| Year | G | H | I | J | K | L |
|---|---|---|---|---|---|---|
| 1970 | | | | | | 12868 |
| 1971 | | | | | | 16127 |
| 1972 | | | | | | 19770 |
| 1973 | | | | | | 21843 |
| 1974 | 13.32582 | 1.96686 | 7.63731 | 12.93975 | 2.33487 | 23950 |
| 1975 | 15.26944 | 4.58464 | 10.09409 | 15.07907 | 5.10911 | 36470 |
| 1976 | 17.04065 | 6.76713 | 12.22355 | 17.01548 | 7.43162 | 48110 |
| 1977 | 17.42533 | 7.21541 | 12.67218 | 17.43194 | 7.91243 | 60420 |
| 1978 | 18.26468 | 8.16500 | 13.63571 | 18.34399 | 8.92744 | 66080 |
| 1979 | 20.28348 | 10.30252 | 15.24717 | 19.90611 | 10.58823 | 74510 |
| 1980 | 20.99176 | 11.01928 | 16.01469 | 20.66934 | 11.36004 | 113600 |
| 1981 | 22.33147 | 12.30811 | 17.43042 | 22.10652 | 12.75432 | 155000 |
| 1982 | 24.11940 | 13.93068 | 19.11054 | 23.86171 | 14.35936 | 153200 |
| 1983 | 25.61914 | 15.18450 | 20.59360 | 25.45632 | 15.73089 | 111300 |
| 1984 | 25.61600 | 15.18136 | 20.59022 | 25.45293 | 15.72750 | 102200 |
| 1985 | 25.37085 | 14.98285 | 20.35126 | 25.20111 | 15.50142 | 92930 |
| 1986 | 23.33022 | 13.23902 | 18.31295 | 23.02122 | 13.60467 | 81820 |
| 1987 | 22.70037 | 12.66853 | 17.66644 | 22.34683 | 12.98605 | 82340 |
| 1988 | 22.31870 | 12.36318 | 16.66927 | 21.32821 | 12.01033 | 84770 |
| 1989 | 22.46384 | 12.47864 | 17.12321 | 21.79073 | 12.45569 | 91220 |
| 1990 | 31.71441 | 21.19497 | 16.76585 | 21.42693 | 12.10476 | 111200 |
| 1991 | 39.89842 | 28.09002 | 17.83204 | 22.52101 | 13.14307 | 120500 |
| 1992 | 36.84530 | 25.66018 | 17.85786 | 22.54683 | 13.16889 | 126900 |
| 1993 | 43.54360 | 21.31113 | 19.47747 | 24.25224 | 14.70270 | |
| 1994 | 45.95423 | 23.57337 | 21.10817 | 26.02022 | 16.19612 | |
| 1995 | 46.72548 | 24.26406 | 21.29598 | 26.22519 | 16.36677 | |
| 1996 | 47.31500 | 24.77513 | 22.36474 | 29.47280 | 15.68568 | |
| 1997 | 48.60308 | 25.83425 | 23.61753 | 30.91650 | 16.81406 | |
| 1998 | 48.90963 | 26.08144 | 23.91349 | 31.26179 | 17.07784 | |
| 1999 | 49.91679 | 26.86813 | 24.87281 | 32.38413 | 17.91919 | |

| Year | M | N | O | P | Q | R |
|---|---|---|---|---|---|---|
| 1970 | 89.6725 | 17.40 | 26.9454 | | 10.8800 | 16.84863 |
| 1971 | 95.5391 | 23.42 | 30.9227 | | 16.6600 | 21.99712 |
| 1972 | 134.0339 | 28.26 | 46.2250 | | 22.7100 | 37.14681 |
| 1973 | 118.7765 | 40.55 | 59.4886 | | 28.9200 | 42.42685 |
| 1974 | 53.3170 | 99.32 | 62.2829 | 65.9147 | 126.4600 | 79.30217 |
| 1975 | 64.1287 | 136.60 | 68.2843 | 62.9915 | 104.0500 | 52.01306 |
| 1976 | 80.8436 | 164.53 | 78.3214 | 73.6966 | 135.9100 | 64.69739 |
| 1977 | 86.3143 | 205.06 | 83.1020 | 81.7262 | 153.4700 | 62.19479 |
| 1978 | 91.6124 | 225.40 | 91.9200 | 92.3329 | 127.1100 | 51.83654 |
| 1979 | 78.4316 | 326.89 | 102.3848 | 102.9401 | 197.0200 | 61.70837 |
| 1980 | 85.9239 | 490.94 | 111.6222 | 107.0086 | 337.4000 | 76.71268 |
| 1981 | 104.2718 | 561.14 | 111.6011 | 123.3284 | 377.3000 | 75.03849 |
| 1982 | 126.2360 | 458.12 | 110.1127 | 118.1794 | 251.1600 | 60.36827 |
| 1983 | 100.1890 | 373.88 | 97.4169 | 103.4137 | 147.8900 | 38.53372 |
| 1984 | 95.7108 | 351.40 | 93.3901 | 89.5205 | 120.7300 | 32.08589 |
| 1985 | 93.4721 | 313.94 | 87.1791 | 88.8559 | 93.8050 | 26.04904 |
| 1986 | 100.6025 | 271.09 | 90.0065 | 76.2365 | 66.8800 | 22.20530 |
| 1987 | 98.2695 | 275.45 | 87.7806 | 91.9988 | 76.5000 | 24.37909 |
| 1988 | 105.1215 | 285.15 | 94.4215 | 91.1577 | 75.6700 | 25.05656 |
| 1989 | 103.9544 | 310.82 | 94.5823 | 93.2760 | 90.2400 | 27.45998 |
| 1990 | 111.2000 | 391.99 | 104.6702 | 98.9857 | 150.2800 | 40.12817 |
| 1991 | 119.9721 | 431.92 | 114.8272 | 114.8752 | 163.4900 | 43.46430 |
| 1992 | 121.1225 | 455.13 | 115.9970 | 120.0072 | | |
| 1993 | | | | 122.6539 | | |
| 1994 | | | | 130.4570 | | |
| 1995 | | | | 132.3004 | | |
| 1996 | | | | 138.2756 | | |
| 1997 | | | | 146.0786 | | |
| 1998 | | | | 147.9220 | | |
| 1999 | | | | 153.8972 | | |

| Year | S | T | U | V |
|---|---|---|---|---|
| 1970 | 65 | | 4.5000 | 14.35 |
| 1971 | 75 | | 4.4868 | 16.88 |
| 1972 | 75 | | 4.1448 | 14.75 |
| 1973 | 75 | | 3.7066 | 18.39 |
| 1974 | 75 | 75 | 3.5500 | 44.92 |
| 1975 | 75 | 75 | 3.5176 | 56.87 |
| 1976 | 75 | 75 | 3.5300 | 59.51 |
| 1977 | 75 | 75 | 3.5251 | 70.00 |
| 1978 | 75 | 75 | 3.3996 | 72.13 |
| 1979 | 79 | 75 | 3.3608 | 95.00 |
| 1980 | 79 | 79 | 3.3267 | 132.21 |
| 1981 | 79 | 79 | 3.3825 | 148.65 |
| 1982 | 80 | 79 | 3.4282 | 121.36 |
| 1983 | 80 | 80 | 3.4548 | 111.09 |
| 1984 | 80 | 80 | 3.5238 | 106.78 |
| 1985 | 80 | 80 | 3.6221 | 99.42 |
| 1986 | 80 | 80 | 3.7033 | 81.33 |
| 1987 | 80 | 80 | 3.7450 | 83.79 |
| 1988 | 84 | 80 | 3.7450 | 80.64 |
| 1989 | 82 | 84 | 3.7450 | 87.75 |
| 1990 | 146 | 82 | 3.7450 | 100.00 |
| 1991 | 191 | 146 | 3.7450 | 100.44 |
| 1992 | 172 | 191 | 3.7450 | 104.77 |
| 1993 | | 172 | | |
| 1994 | | 172 | | |
| 1995 | | 172 | | |
| 1996 | | 172 | | |
| 1997 | | 172 | | |
| 1998 | | 172 | | |
| 1999 | | 172 | | |

## Appendix B: Holt-Winters Exponential Smoothing for Saudi Arabian ME

| Year | Actual ME | Overall (S) | Cycle (I) | Trend (b) | Forecast ME |
|---|---|---|---|---|---|
| 1965 | | | 0.7958 | | |
| 1966 | | | 0.8994 | | |
| 1967 | | | 1.1661 | | |
| 1968 | | | 1.1964 | | |
| 1969 | | | 1.0955 | | |
| 1970 | | | 1.0805 | | |
| 1971 | | | 0.9666 | | |
| 1972 | | | 0.7998 | | |
| 1973 | | 8.5197 | 0.7958 | 1.0149 | |
| 1974 | 5.8014 | 9.2229 | 0.8994 | 1.0149 | 8.5752 |
| 1975 | 11.1834 | 9.9865 | 1.1661 | 1.0149 | 11.9379 |
| 1976 | 15.4529 | 10.8648 | 1.1964 | 1.0149 | 13.1618 |
| 1977 | 13.2471 | 11.6962 | 1.0955 | 1.0149 | 13.0147 |
| 1978 | 14.5432 | 12.5586 | 1.0805 | 1.0149 | 13.7337 |
| 1979 | 14.2000 | 13.4542 | 0.9666 | 1.0149 | 13.1198 |
| 1980 | 12.3516 | 14.3647 | 0.7998 | 1.0149 | 11.5724 |
| 1981 | 13.4881 | 15.3242 | 0.7958 | 1.0149 | 12.2390 |
| 1982 | 19.7841 | 16.5184 | 0.8994 | 1.0149 | 14.6950 |
| 1983 | 22.0362 | 17.6108 | 1.1661 | 1.0149 | 20.4449 |
| 1984 | 18.8518 | 18.5194 | 1.1964 | 1.0149 | 22.2835 |
| 1985 | 21.1829 | 19.5042 | 1.0955 | 1.0149 | 21.4006 |
| 1986 | 20.9886 | 20.4405 | 1.0805 | 1.0149 | 22.1698 |
| 1987 | 19.0954 | 21.3249 | 0.9666 | 1.0149 | 20.7382 |
| 1988 | 16.6419 | 22.1840 | 0.7998 | 1.0149 | 17.8675 |
| 1989 | 16.5242 | 22.9679 | 0.7958 | 1.0149 | 18.4616 |
| 1990 | 22.8700 | 23.8968 | 0.8994 | 1.0149 | 21.5696 |
| 1991 | 34.8965 | 25.0320 | 1.1661 | 1.0149 | 29.0486 |
| 1992 | 32.9770 | 26.0924 | 1.1964 | 1.0149 | 31.1621 |
| 1993 | | | | | 29.6971 |
| 1994 | | | | | 30.3845 |
| 1995 | | | | | 28.1631 |
| 1996 | | | | | 24.1156 |
| 1997 | | | | | 24.8023 |
| 1998 | | | | | 28.9433 |
| 1999 | | | | | 38.7091 |

(Values in billions of 1990 dollars)

## Appendix C: Holt-Winters Exponential Smoothing for Saudi Arabian GDP

| Year | Actual GDP | Overall (S) | Cycle (I) | Trend (b) | Forecast GDP |
|---|---|---|---|---|---|
| 1973 | | 60.7075 | 1.9866 | 5.2072 | |
| 1974 | 62.2829 | 57.7843 | −1.3773 | 5.2072 | 65.9147 |
| 1975 | 68.2843 | 68.4894 | −0.6093 | 5.2072 | 62.9915 |
| 1976 | 78.3214 | 77.8963 | 1.9866 | 5.2072 | 73.6966 |
| 1977 | 83.1020 | 87.7349 | −1.3773 | 5.2072 | 81.7262 |
| 1978 | 91.9200 | 95.7463 | −0.6093 | 5.2072 | 92.3329 |
| 1979 | 102.3848 | 103.1787 | 1.9866 | 5.2072 | 102.9401 |
| 1980 | 111.6222 | 118.7305 | −1.3773 | 5.2072 | 107.0086 |
| 1981 | 111.6011 | 110.9856 | −0.6093 | 5.2072 | 123.3284 |
| 1982 | 110.1127 | 99.5838 | 1.9866 | 5.2072 | 118.1794 |
| 1983 | 97.4169 | 84.9226 | −1.3773 | 5.2072 | 103.4137 |
| 1984 | 93.3901 | 81.6622 | −0.6093 | 5.2072 | 89.5205 |
| 1985 | 87.1791 | 72.4065 | 1.9866 | 5.2072 | 88.8559 |
| 1986 | 90.0065 | 87.4009 | −1.3773 | 5.2072 | 76.2365 |
| 1987 | 87.7806 | 83.9639 | −0.6093 | 5.2072 | 91.9988 |
| 1988 | 94.4215 | 89.4460 | 1.9866 | 5.2072 | 91.1577 |
| 1989 | 94.5823 | 94.3877 | −1.3773 | 5.2072 | 93.2760 |
| 1990 | 104.6702 | 107.6814 | −0.6093 | 5.2072 | 98.9857 |
| 1991 | 114.8272 | 116.1773 | 1.9866 | 5.2072 | 114.8752 |
| 1992 | 115.9970 | 118.0560 | −1.3773 | 5.2072 | 120.0072 |
| 1993 | | | −0.6093 | | 122.6539 |
| 1994 | | | 1.9866 | | 130.4570 |
| 1995 | | | −1.3773 | | 132.3004 |
| 1996 | | | −0.6093 | | 138.2756 |
| 1997 | | | 1.9866 | | 146.0786 |
| 1998 | | | −1.3773 | | 147.9220 |
| 1999 | | | | | 153.8972 |

(Values in billions of 1990 dollars)

## Appendix D: Calculations for the RSAF FMS Decision Analysis Model

**Initial Conditions:**

RSAF FMS Estimate = \$3.25 billion
Model 2 ME = \$26.7 billion
Percent ME RSAF FMS = 11% = 0.11
Model 2 FMS Estimate = (Model 2 ME)(Percent ME RSAF FMS)
= \$2.937 billion
Risk Tolerance = R = \$1 billion
King = 20
Preference for the U.S. = (King)(5%) = 100% = 1
New Requested = 90% = 0.9
Weight = w = 2/3

**Calculations:**

$$\text{RSAF FMS Value to U.S.} = (w)(1-e^{-(\text{New Production})/R}) + (1-w)(1-e^{-(\text{Stock Sales})/R})$$

New Production = (New Requested)(Final Sale)

Stock Sales = (1-New Requested)(Final Sale)

Final Sale = 0.185(FMS to RSAF) + 0.63(0.9(FMS to RSAF))
+ 0.185(0.8(FMS to RSAF)

**For the RSAF FMS Estimate:**

FMS to RSAF =

0.185(0.7)(RSAF FMS Estimate)(Preference for U.S.)
+ 0.63(0.8)(RSAF FMS Estimate)(Preference for U.S.)
+ 0.185(RSAF FMS Estimate)(Preference for U.S.)

**For the Model 2 FMS Estimate:**

FMS to RSAF =

0.185(0.95)(Model 2 FMS Estimate)(Preference for U.S.)
+ 0.63(Model 2 FMS Estimate)(Preference for U.S.)
+ 0.185(Model 2 FMS Estimate)(Preference for U.S.)

## Appendix E: RSAF FMS Decision Analysis

### Computer Program

```
value Model_2_ME=26.7;
value Percent_ME_RSAF_FMS=.11;
value RSAF_FMS_Estmate=3.25;
value Risk_Tolerance=1;
value King=20;
value New_Requested=.9;
value weight=2/3;
value Model_2_FMS_Estimate=Model_2_ME*Percent_ME_RSAF_FMS;
value Preference_for_U_S_=.05*King;
decision Which_estimate_.{RSAF,Model_2};
chance
Actual_RSAF_FMS.{Higher,Closer,Lower}={.185,.63,.185};
value FMS_to_RSAF|Which_estimate_,Actual_RSAF_FMS=
                                        // Which_estimate_.RSAF
     RSAF_FMS_Estmate*Preference_for_U_S_,
          //   Actual_RSAF_FMS.Higher
     RSAF_FMS_Estmate*.8*Preference_for_U_S_,
          //   Actual_RSAF_FMS.Closer
     RSAF_FMS_Estmate*.7*Preference_for_U_S_,
          //   Actual_RSAF_FMS.Lower
                                        //
Which_estimate_.Model_2
     Model_2_FMS_Estimate*Preference_for_U_S_,
          //   Actual_RSAF_FMS.Higher
     Model_2_FMS_Estimate*Preference_for_U_S_,
          //   Actual_RSAF_FMS.Closer
     Model_2_FMS_Estimate*.95*Preference_for_U_S_;
          //   Actual_RSAF_FMS.Lower
chance U_S__Congress.{Fav,Neutral,Unfav}={.185,.63,.185},
=
     FMS_to_RSAF,          // U_S__Congress.Fav
     .9*FMS_to_RSAF,       // U_S__Congress.Neutral
     .8*FMS_to_RSAF;       // U_S__Congress.Unfav
value Final_Sale|U_S__Congress=
     U_S__Congress,        // U_S__Congress.Fav
     U_S__Congress,        // U_S__Congress.Neutral
     U_S__Congress;        // U_S__Congress.Unfav
value Stock_Sales=Final_Sale*(1-New_Requested);
value New_Production=Final_Sale*New_Requested;
value RSAF_FMS_Value_to_U_S_=((1-weight)*(1-@exp(-
Stock_Sales/Risk_Tolerance)))+(weight*(1-@exp(-
New_Production/Risk_Tolerance)));
sequence:
decide to Which_estimate_ then
gamble on Actual_RSAF_FMS then
gamble on U_S__Congress and get RSAF_FMS_Value_to_U_S_
```

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# Vita

Lieutenant Robert S. Renfro, II was born on 8 May 1971 in Portland, Oregon. He graduated from Bitburg American High School, Germany in 1989 and attended Northwestern Preparatory School in California. He then entered undergraduate studies at the U.S. Air Force Academy (USAFA) in Colorado Springs, Colorado. He graduated in June 1994 with a Bachelor of Science Degree in Operations Research and a minor in Arabic. During his tenure at the Academy, he had the opportunity to travel to and study at the University of Aleppo, Syria. Lieutenant Renfro received his commission in the U.S. Air Force in June 1994. He then served as an intern and research assistant at the National Council on U.S.-Arab Relations in Washington, DC. Following this program, he entered the Graduate School of Engineering, Air Force Institute of Technology (AFIT) at Wright-Patterson AFB, Ohio. While at AFIT, he was selected as a Malone Fellow of the National Council on U.S.-Arab Relations and traveled to Saudi Arabia and Oman. He also participated in the activities of the Ohio Committee on U.S.-Arab Relations. Following his graduation from the Air Force Institute of Technology in March of 1996, Lieutenant Renfro will serve with the National Air Intelligence Center (NAIC) located at Wright-Patterson AFB, Ohio.

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This thesis focuses on means of forecasting Saudi Arabian military expenditures and the effect of such expenditures on the United States. Saudi Arabia is one of the largest purchasers of American arms and will continue to be for many years. Saudi Arabia has experienced several recent changes in economic and government policy.

Using exponential smoothing techniques and linear regression, we isolated several trends in Saudi Arabian military expenditures. Using two linear regression models, military expenditures were then forecast with excellent results. The first model considered the assumption that Gulf War spending would continue. This model uses Saudi Arabian Gross Domestic Product lagged by three years and the current year force size as explanatory variables. The second model considers the assumption of post-war reductions and is based only on the Saudi Arabian Gross Domestic Product lagged by three years.

Using decision analysis, it was possible to consider the implications of these forecasts for the United States. The decision analysis model considered several relevant contemporary issues, including succession of the Saudi Arabian King, the Foreign Military Sales policy of the United States, associated uncertainties, and risk.

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